THE SOUTH WALES INSTITUTE OF ENGINEERS.

[EMBRACING THE COALFIELDS OF SOUTH WALES AND MONMOUTHSHIRE, THE FOREST OF DEAN, GLOUCESTERSHIRE AND SOMERSETSHIRE.]

FOUNDED 1857—INCORPORATED BY ROYAL CHARTER, 1881.

PROCEEDINGS.

VOL. XXXVII.

THE SIXTY-FOURTH SESSION.
1921.

EDITED BY THE SECRETARY.

PUBLISHED BY THE INSTITUTE, PARK PLACE, CARDIFF.

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1922.

CONTENTS OF PROCEEDINGS.

VOLUME XXXVII.

JANUARY 28, 1921, TO NOVEMBER 17, 1921.

(Comprising Parts 1, 2, 3, 4, 5 and 6.)

No. 1. VOLUME XXXVII., issued March 10, 1921, price 5s.

No. 2. VOLUME XXXVII., issued May 24, 1921, price 5s.

No. 3. VOLUME XXXVII., issued July 7, 1921, price 5s.

No. 4. Volume XXXVII., issued Sept. 24, 1921, price 10*s*.

No. 5. Volume XXXVII., issued Nov. 10, 1921, price 10*s*.

No. 6. Volume XXXVII., issued Jan. 20, 1922, price 10*s*.

PAST PRESIDENTS
OF THE
SOUTH WALES INSTITUTE OF ENGINEERS.
1921.

	SESSIONS	
MENELAUS, WILLIAM, M.Inst.C.E. ...	1857–58 ; 1864–65 ...	(Deceased)
ROGERS, EBENEZER	1858–59	(Deceased)
CLARK, WILLIAM SOUTHERN	1859–60	(Deceased)
BROUGH, LIONEL	1860–61	(Deceased)
ADAMS, WILLIAM, A.M.Inst.C.E. ...	1861–62	(Deceased)
EVANS, THOMAS	1862–63	(Deceased)
BASSET, ALEXANDER, M.Inst.C.E. ...	1863–64	(Deceased)
MARTIN, GEORGE	1865–66 ; 1866–67 ...	(Deceased)
BEDLINGTON, RICHARD	1867–68 ; 1868–69 ...	(Deceased)
LEWIS, Sir WILLIAM THOMAS, Bart., M.Inst.C.E. (afterwards Lord Merthyr of Senghenydd), G.C.V.O.	1869–70 ; 1870–71 & 1889–90 ; 1890–91	(Deceased)
STEEL, T. DYNE, M.Inst.C.E. ...	1871–72 ; 1872–73 ...	(Deceased)
BROWN, THOMAS FORSTER, M.Inst.C.E.	1873–74 ; 1874–75 & 1891–92 ; 1892–93	(Deceased)
BROGDEN, JAMES, F.G.S.	1875–76 ; 1876–77 ...	(Deceased)
LAYBOURNE, RICHARD	1877–78 ; 1878–79 ...	(Deceased)
McMURTRIE, JAMES, F.G.S. ...	1879–80 ; 1880–81 ...	(Deceased)
WILLIAMS, EDWARD, M.Inst.C.E. ...	1881–82 ; 1882–83 ...	(Deceased)
COLQUHOUN, JAMES	1883–84 ; 1884–85 ...	(Deceased)
HOOD, ARCHIBALD	1885–86 ; 1886–87 ...	(Deceased)
MARTIN, EDWARD PRITCHARD, M.Inst. C.E.	1887–88 ; 1888–89 ...	(Deceased)
STEVENS, ARTHUR J., M.I.Mech.E.	1893–94 ; 1894–95	
MARTIN, HENRY WILLIAM, M.Inst.C.E.	1895–96 ; 1896–97	
JORDAN, HENRY KEYES, D.Sc., F.G.S.	1897–98 ; 1898–99	
EVENS, THOMAS, M.Inst.C.E. ...	1899–00 ; 1900–01	
RICHES, T. HURRY, M.Inst.C.E. ...	1901–02 ; 1902–03 ...	(Deceased)
HANN, EDMUND MILLS, M.Inst.C.E.	1903–04 ; 1904–05	
DEAKIN, THOS. HEDGES, M.Inst.C.E.	1905–06 ; 1906–07	
WIGHT, WILLIAM DUNDAS	1907–08 ; 1908–09 & July 1911 to Dec. 1911	
REES, ITHEL TREHARNE, M.Inst.C.E.	1909–10 ; 1910 to July 1911 ...	(Deceased)
GALLOWAY, W., D.Sc., F.G.S., F.I.D.	1912	
ELLIOTT, A. C., D.Sc., M.Inst.C.E.	1913	(Deceased)
ATKINSON, Sir W. N., LL.D. ...	1913 (May 22 to Dec. 31, 1913)	
WALES, HENRY T.	1914	
GRIFFITHS, E. H., M.A., F.R.S. ...	1915	
STEWART, WM.	1916	
BRAMWELL, HUGH, O.B.E.	1917	
TALLIS, JOHN FOX	1918	
DAWSON, EDWARD, M.I.Mech.E. ...	1919	
LEWIS, J. DYER	1920	

THE SOUTH WALES INSTITUTE OF ENGINEERS.

LIST OF OFFICE-BEARERS FOR SESSION 1921.

President.

Brown, W. Forster, M.Inst.C.E.	Session 1921.

Past Presidents.

	Sessions
Stevens, Arthur J., M.I.Mech.E.	1893–94, 1894–95.
Martin Henry W., M.Inst.C.E.	1895–96, 1896–97.
Jordan Henry K., D.Sc., F.G.S....	1897–98, 1898–99.
Evens, Thomas, M.Inst.C.E.	1899–00, 1900–01.
Hann, E. M., M.Inst.C.E.	1903–04, 1904–05.
Deakin, T. H., M.Inst.C.E.	1905–06, 1906–07.
Wight, Wm. D.	1907–08, 1908–09 & July to Dec. 1911.
Galloway, W., D.Sc., F.G.S., F.I.D.	1912.
Wales, Henry T.	1914.
Stewart, Wm.	1916.
Bramwell, Hugh, O.B.E.	1917.
Tallis, John Fox	1918.
Dawson, Edward, M.I.Mech.E.	1919.
Lewis, J. Dyer	1920.

Vice-Presidents.

Roberts, David E., M.Inst.C.E.	Cardiff.
Johnson, Wm.	Bridgend.
Vachell, Theodore, A.M.Inst.C.E.	Newport.
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Hood, W. W.	Cardiff.
Thomas, Hubert Spence	Whitchurch, Glam.

Members of Council.

Knox, George, F.G.S., M.I.M.E.	Radyr.
Davies, J. C.	Gowerton.
Hannah, David	Penarth.
Johnson, T. Allan	Cardiff.
Bacon, Frederic, M.A., M.I.E.E.	Swansea.
Sugden, Thomas, Wh.Sc., M.I.Mech.E.	London.
Jones, Howell R.	Dowlais.
Gilbertson, Francis W.	Pontardawe.
O'Connor, W., F.G.S.	Argoed, near Newport.
Davison, J. W., M.B.E., M.I.Mech.E.	Pontypridd.
Llewelyn, Sir Leonard W., K.B.E.	Newport, Mon.
Thomas, Trevor F., A.M.Inst.C.E.	Whitchurch, Glam.
Nicholas, Benjamin	Pontypool.
Jacob, F. Llewellin	Ferndale.
Hutchinson, J. W.	Tondu.
Seyler, C. A., B.Sc.	Swansea.
Hann, E. L....	Aberdare.
Davies, D. Farr, F.G.S.	Cross Hands, Llanelly.

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Price, Martin	Institute Buildings, Park Place, Cardiff.

Auditors.

McDonald, W., F.C.A., & Rees	Cardiff.

Treasurer.

The Manager, Lloyds Bank, Limited	Cardiff.

Solicitors.

Kensholes & Prosser	Aberdare.

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1906. A Second Prize was awarded to Mr. George Roblings for his Paper "Separation (Sizing) and Washing of Coal."

1907. A First Prize was awarded to Mr. Daniel Davies, and a Second Prize to Mr. Gath J. Fisher, for their Papers on "Pumping and Drainage," and also on "Sinking Shafts."

1908. A First Prize was awarded to Mr. H. A. Staples, a Second Prize to Mr. George Roblings, and a Third Special Prize to Mr. M. D. Williams, for their Papers "As to the Best Methods of Working Seams of Coal in Steep Measures."

1909. A First Prize was awarded to Mr. William Trimmer, and a Second Prize to Mr. C. W. Jordan, A.M.I.Mech.E., for their Papers on "General Lay-out and Equipment of a Complete Set of Engineering Shops for a Modern Colliery with an Output of about 2,000 tons per day."

1910. A First Prize was awarded to Mr. George Roblings, and a Second Prize to Mr. Noah T. Williams, for their Papers on "Washing and Sorting of Small Coal."

1913. Special Prize awarded Mr. Will Gregson for his Paper "The Most Approved Methods of Hauling the Coal from the Working Faces to the Pit Bottom."

1914. Special Prizes awarded Messrs. J. Williams and S. R. Cound for their Papers on "How to Improve Welsh Tinplate Rolling-mill Practice."

1918. A First Prize was awarded to Mr. W. T. Lane, and a Second to Mr. W. H. Casmey, for their Papers on "Fuel Economy in Power Production (or Utilisation of Waste Heat)."

1920. A First Prize was awarded to Mr. R. C. Morgan for his Paper on "Causes of Subsidences and the best Safeguards for their Prevention."

1921. Subject selected: "Improved Mechanical Methods for bringing Coal from long distances in view of the necessity for Increased Output." 1st Prize £20, 2nd £10.

SPENCE THOMAS SCHOLARSHIP.

(Founded in 1918 by Mr. H. Spence Thomas for the encouragement of the Members of the Associations of Students of the Institute.)

The interest on £1,000 5 per cent. War Loan Stock shall be devoted to the Scholarship.

The Holder of the Scholarship must be a Member of one of the Students' Associations of the Institute, and must be a Student at one of the Colleges, Schools, or Institutions recognised as suitable by the Council of the Institute.

The Council of the Institute shall award the Scholarship upon Reports presented for its consideration by the Heads of any of the above Colleges, Schools, or Institutions, on the completion of one year's study by any student.

The College, School, or Institution shall present an annual report to the Council on the work and progress of the Scholar to whom the Scholarship shall have been awarded, and the Council retains the right of withholding or cancelling the Scholarship, if in its opinion the progress of the Scholar is unsatisfactory.

In the award of the Scholarship the professional knowledge and practical experience of the candidate shall be taken into consideration.

No candidate will be elected to the Scholarship until he has satisfied the Council that his physical condition is satisfactory.

The Scholarship shall be awarded for a term of one, two, or more years in the discretion of the Council. The Scholar to briefly report at the end of each year upon the work accomplished.

The Council reserves the right to withhold the Scholarship if no candidate of sufficient merit presents himself.

1919–1921. The Spence Thomas Scholarship of £50 per annum was awarded to Mr. William John Gilbert, Nantyglo, for a period of three years, tenable at the School of Mines, Treforest.

INSTITUTE SCHOLARSHIP IN ENGINEERING.

Granted by the Council in 1904, and tenable for three years at the University College of South Wales and Monmouthshire.

1904.—An EXHIBITION of £60, awarded to Mr. Ernest Clarke Stroud, Chatham.

1905-08.—A SCHOLARSHIP of £70 per annum, awarded to Mr. E. C. Stroud.

1908-11.—A SCHOLARSHIP of £70 per annum, awarded to Mr. Ivor Richard Cox, Cardiff.

1912.—An EXHIBITION of £60, awarded to Mr. Victor John French, Chatham.

1912-15.—A SCHOLARSHIP of £70 per annum, awarded to Mr. Victor John French.

1915-18.—A SCHOLARSHIP of £70 per annum, awarded to Mr. E. W. H. Knight, Devonport.

NOTE.—Mr. Knight was unable to take up the Scholarship he had won, and an honorarium of £10 was granted him by the Council, also a Certificate to the effect that he had won the Scholarship.

1919-21—An EXHIBITION of £13 (plus a bonus of £15) per annum, awarded to Mr. E. G. Davies, Cardiff. (Won in 1915.)

1919-21.—A SCHOLARSHIP of £70 per annum, plus a bonus of £15 per annum, awarded to Mr. Myrddin David, County School, Porth, and

1919-20.—An EXHIBITION of £30 per annum for two years, awarded to Mr. J. Selwyn Caswell, Ebbw Vale.

INSTITUTE SCHOLARSHIP IN ENGINEERING.

Granted by the Council in 1921, and tenable for three years at the UNIVERSITY COLLEGE OF SWANSEA.

Session 1921-1922 to 1923-1924. A Scholarship of £70 per annum, awarded to Mr. John Brook Fortune, Swansea.

ADVERTISEMENT.

DIRECTIONS TO BINDER.

VOLUME XXXVII.

COMPRISES PARTS 1, 2, 3, 4, 5 and 6.

ORDER OF BINDING.

First :—Title Page, Contents of Volume, etc., pages (i) to (xi) inclusive.

Second :—Photograph of President (Mr. W. Forster Brown), to face page 1. (See Part 1.)

Third :—Proceedings, pages 1 to 564 inclusive.

Fourth :—Index to Volume xxxvi., pages 565 to 576 inclusive.

ISSUED MARCH 10th, 1921.

VOL. XXXVII.] [No. 1.

PROCEEDINGS

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FOUNDED 1857—INCORPORATED BY ROYAL CHARTER 1881.

ORDINARY GENERAL MEETING, CARDIFF, JANUARY 28TH, 1921.

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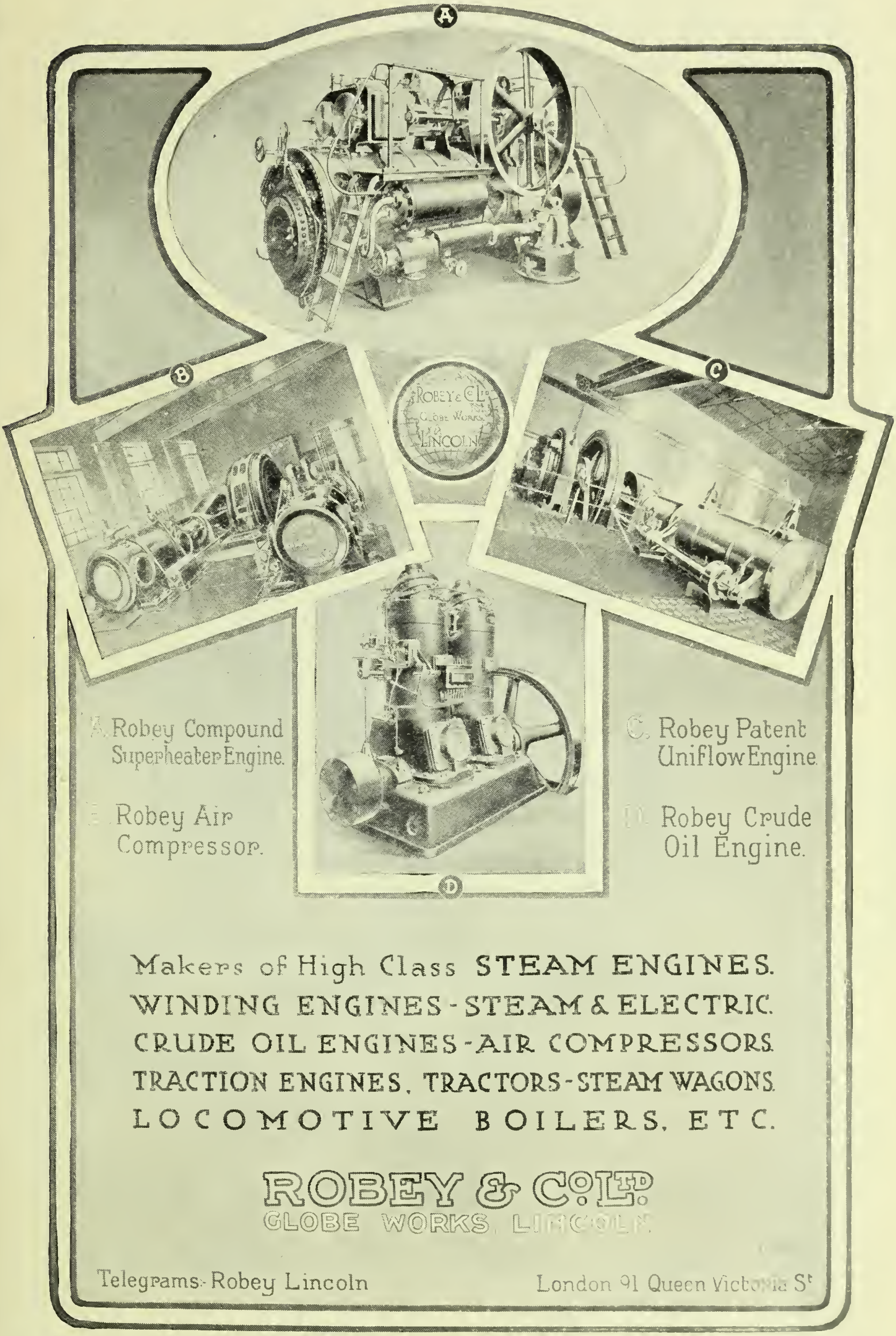
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PAST PRESIDENTS

OF THE

SOUTH WALES INSTITUTE OF ENGINEERS.

1921.

	SESSIONS	
MENELAUS, WILLIAM, M.Inst.C.E. ...	1857–58 ; 1864–65 ...	(Deceased)
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LEWIS, Sir WILLIAM THOMAS, Bart., M.Inst.C.E. (afterwards Lord Merthyr of Senghenydd), G.C.V.O.	1869–70 ; 1870–71 & 1889–90 ; 1890–91	(Deceased)
STEEL, T. DYNE, M.Inst.C.E. ...	1871–72 ; 1872–73 ...	(Deceased)
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EVENS, THOMAS, M.Inst.C.E. ...	1899–00 ; 1900–01	
RICHES, T. HURRY, M.Inst.C.E. ...	1901–02 ; 1902–03 ...	(Deceased)
HANN, EDMUND MILLS, M.Inst.C.E.	1903–04 ; 1904–05	
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REES, ITHEL TREHARNE, M.Inst.C.E.	1909–10 ; 1910 to July 1911 ...	(Deceased)
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ELLIOTT, A. C., D.Sc., M.Inst.C.E.	1913	(Deceased)
ATKINSON, Sir W. N., LL.D. ...	1913 (May 22 to Dec. 31, 1913)	
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President.

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Jordan, Henry K., D.Sc., F.G.S.	1897–98, 1898–99.
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Atkinson, Sir W. N., LL.D.	May 22 to Dec. 31, 1913
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Lewis, J. Dyer	1920.

Vice-Presidents.

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Vachell, Theodore, A.M.Inst.C.E.	Newport.
Chamen, W. A., M.I.E.E.	Cardiff.
Hood, W. W.	Cardiff.
Thomas, Hubert Spence	Whitchurch, Glam.

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Davies, J. C.	Gowerton.
Hannah, David	Penarth.
Johnson, T. Allan	Cardiff.
Bacon, Frederic, M.A., M.I.E.E.	Cardiff.
Sugden, Thomas, Wh.Sc., M.I.Mech.E.	London.
Jones, Howell R.	Dowlais.
Gilbertson, Francis W.	Pontardawe.
O'Connor, W., F.G.S.	Argoed, near Newport.
Davison, J. W.	Pontypridd.
Llewelyn, Sir Leonard W., K.B.E.	Newport, Mon.
Thomas, Trevor F., A.M.Inst.C.E.	Whitchurch, Glam.
Nicholas, Benjamin	Pontypool.
Jacob, F. Llewellin	Ferndale.
Hutchinson, J. W.	Tondu.
Seyler, C. A., B.Sc.	Swansea.
Hann, E. L.	Aberdare.
Davies, D. Farr, F.G.S.	Cross Hands, Llanelly.

Secretary.

Price, Martin	Institute Buildings, Park Place, Cardiff.

Auditors.

McDonald, W., F.C.A., & Rees	Cardiff.

Treasurer.

The Manager, Lloyds Bank, Limited	Cardiff.

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1905.—A First Prize was awarded to Mr. W. Waplington for his Paper "Description and Design of the Best Arrangements of Equipment of the Bottom, with a Radius of 400 yards, of a Pair of Pits to be Upcast and Downcast Respectively."

1906.—A Second Prize was awarded to Mr. George Roblings for his Paper "Separation (Sizing) and Washing of Coal."

1907.—A First Prize was awarded to Mr. Daniel Davies, and a Second Prize to Mr. Gath J. Fisher, for their Papers on "Pumping and Drainage," and also on "Sinking Shafts."

1908.—A First Prize was awarded to Mr. H. A. Staples, a Second Prize to Mr. George Roblings, and a Third Special Prize to Mr. M. D. Williams, for their Papers "As to the Best Methods of Working Seams of Coal in Steep Measures."

1909.—A First Prize was awarded to Mr. William Trimmer, and a Second Prize to Mr. C. W. Jordan, A.M.I.Mech.E., for their Papers on "General Lay-out and Equipment of a Complete Set of Engineering Shops for a Modern Colliery with an Output of about 2,000 tons per day."

1910.—A First Prize was awarded to Mr. George Roblings, and a Second Prize to Mr. Noah T. Williams, for their Papers on "Washing and Sorting of Small Coal."

1913.—Special Prize awarded Mr. Will Gregson for his Paper "The Most Approved Methods of Hauling the Coal from the Working Faces to the Pit Bottom."

1914.—Special Prizes awarded Messrs. J. Williams and S. R. Cound for their Papers on "How to Improve Welsh Tinplate Rolling-mill Practice."

1918.—A First Prize was awarded to Mr. W. T. Lane, and a Second to Mr. W. H. Casmey, for their Papers on "Fuel Economy in Power Production (or Utilisation of Waste Heat)."

1920.—A First Prize was awarded to Mr. R. C. Morgan for his Paper "Causes of Subsidences and the best Safeguards for their Prevention."

INSTITUTE SCHOLARSHIP IN ENGINEERING.

Granted by the Council in 1904, and tenable for three years at the University College of South Wales and Monmouthshire.

1904.—An EXHIBITION of £60, awarded to Mr. Ernest Clarke Stroud, Chatham.

1905-08.—A SCHOLARSHIP of £70 per annum, awarded to Mr. E.C. Stroud.

1908-11.—A SCHOLARSHIP of £70 per annum, awarded to Mr. Ivor Richard Cox, Cardiff.

1912.—An EXHIBITION of £60, awarded to Mr. Victor John French, Chatham.

1912-15.—A SCHOLARSHIP of £70 per annum, awarded to Mr. Victor John French.

1915-18.—A SCHOLARSHIP of £70 per annum, awarded to Mr. E. W. H. Knight, Devonport,

Note.—Mr. Knight was unable to take up the Scholarship he had won, and an honorarium of £10 was granted him by the Council, also a Certificate to the effect that he had won the Scholarship.

1919-21.—An EXHIBITION of £13 (plus a bonus of £15) per annum, awarded to Mr. E. G. Davies, Cardiff. (Won in 1915.)

1919-21.—A SCHOLARSHIP of £70 per annum, plus a bonus of £15 per annum, awarded to Mr. Myrddin David, County School, Porth, and

1919-20.—An EXHIBITION of £30 per annum for two years, awarded to Mr. J. Selwyn Caswell, Ebbw Vale.

NOTICES.

The Editor of these Proceedings is directed to make it known that the Authors alone are responsible for the facts and opinions contained in their respective Papers, and the individual speakers for their statements made in discussion.

He is also directed to state that the COPYRIGHT of all the Papers and Discussions published in these Proceedings is the exclusive property of the Institute, and reproduction of any of the Papers is prohibited unless in each case the consent of the Council has been previously obtained.

PROCEEDINGS.

Back Numbers of the Proceedings have now been bound, from Vol. I. inclusive, in Volumes, in strong Duro-Flexile Cloth, and may be obtained from the Secretary at £1. 1s. per volume, or separate back numbers can be had at the various prices marked on the covers.

CHANGE OF RESIDENCE.

The Secretary would be obliged by Members notifying to him any alteration in their addresses at the earliest date.

INSTITUTE BUILDING.

The Institute, Park Place, Cardiff, is open for the use of Members on Week-days from 10 a.m. to 5 p.m.

The New Library is now open for the use of Members, and the technical journals and other periodicals will be found on the tables in that room, instead of in the Council Chamber.

SPENCE THOMAS SCHOLARSHIP.

(Founded in 1918 by Mr. H. Spence Thomas for the encouragement of the Members of the Associations of Students of the Institute.)

The interest on £1,000 5 per cent. War Loan Stock shall be devoted to the Scholarship.

The Holder of the Scholarship must be a Member of one of the Students' Associations of the Institute, and must be a Student at one of the Colleges, Schools, or Institutions recognised as suitable by the Council of the Institute.

The Council of the Institute shall award the Scholarship upon Reports presented for its consideration by the Heads of any of the above Colleges, Schools, or Institutions, on the completion of one year's study by any student.

The College, School, or Institution shall present an annual report to the Council on the work and progress of the Scholar to whom the Scholarship shall have been awarded, and the Council retains the right of withholding or cancelling the Scholarship, if in its opinion the progress of the Scholar is unsatisfactory.

In the award of the Scholarship the professional knowledge and practical experience of the candidate shall be taken into consideration.

No candidate will be elected to the Scholarship until he has satisfied the Council that his physical condition is satisfactory.

The Scholarship shall be awarded for a term of one, two, or more years in the discretion of the Council. The Scholar to briefly report at the end of each year upon the work accomplished.

The Council reserves the right to withhold the Scholarship if no candidate of sufficient merit presents himself.

1919–1921. The Spence Thomas Scholarship of £50 per annum was awarded to Mr. William John Gilbert, Nantyglo, for a period of three years, tenable at the School of Mines, Treforest.

ADVERTISEMENTS.

For particulars of advertisement space in these publications, apply to The Business Statistics Company, Ltd., Baltic House, Cardiff.

CONTENTS.

No. 1. VOLUME XXXVII., issued March 10th, 1921, price 5s.

MR. WESTGARTH FORSTER BROWN, M.Inst.C.E.

President of the South Wales Institute of Engineers

SESSION 1921

PROCEEDINGS.

Ordinary General Meeting, Cardiff, January 28, 1921.

New President's Inaugural Address.

An Ordinary General Meeting of the South Wales Institute of Engineers was held at the Institution, Cardiff, on Friday, January 28, 1921.

The chair at the outset was taken by Mr. J. Dyer Lewis, H.M. Divisional Inspector of Mines, the retiring President.

The minutes of the preceding Special and Ordinary General Meetings, held on November 26, 1920, and of the Special General Meeting held on December 16, 1920, were read and confirmed.

The Retiring President.

The Retiring President said it gave him much pleasure to announce that the Council had elected Mr. Westgarth Forster Brown to the presidential chair for the year. It was hardly necessary for him to introduce Mr. Forster Brown to the meeting. He was the principal member of the oldest firm of civil and mining engineers in Cardiff and South Wales—a firm that was founded by his father, the late Mr. Thomas Forster Brown, who for two presidential periods filled the chair to which his no less distinguished son had now been called. The members of the Institute were to be congratulated upon having

The Retiring President.

as their President one who occupied so high a position in the profession, and who had such important duties to discharge in connection with that profession all over the country. He (Mr. Dyer Lewis) desired to thank the past presidents, the Council, and members and students generally for the unstinted support they had extended to him during his year of office. Especially were his thanks due to Mr. Martin Price, their excellent and genial Secretary. During the past year attendance at the meetings of the Institute was uniformly good, particularly at the evening meetings, which appeared to be popular, enabling, as they did, those members to attend whose professional duties prevented their presence at day meetings. The printing of the 'Proceedings' had been a source of anxiety to the Council and to the Chairman of the Finance Committee, owing to the high cost of production during and since the war; but by an arrangement recently entered into it was hoped to issue the 'Proceedings' more frequently and at a reduced cost. He had again to thank members for their co-operation and courtesy, and to call upon Mr. Westgarth Forster Brown to take the chair. (Applause.)

The New President.

The New President was cordially greeted. He said he desired to thank the Council very heartily for the great honour they had done him in electing him to that position. The fact that his father had occupied the same position naturally enhanced the gratification he felt. It was always a source of pleasure to him to see how well his father's work in connection with the Institute was remembered. (Applause.) He (the speaker) realised that in the past he had not attended the meetings of the Institute as often as he would have liked; for this they must blame the exigencies of the profession to which they and he belonged. Clever as engineers were deemed to be, and many as were the wonderful things they had accomplished in the world, they had not yet invented a means for

being in two places at one and the same time. (Laughter.) He need hardly assure members that he would do his best to satisfactorily perform the duties of the position to which they had called him; and with their support, and that of the Secretary, he looked forward with confidence. (Applause.) **The New President.**

Thanks to the Ex-President.

The President. The PRESIDENT said his first duty was a very pleasant one. It was to propose a hearty vote of thanks to Mr. Dyer Lewis, the retiring President, for the able way in which he had performed the duties of that office during the past year. (Applause.) Mr. Dyer Lewis had devoted a great deal of time to the affairs of the Institute during his presidency, and had brought it through a period of some anxiety. It was the first year in which the Institute might be said to have resumed its full pre-war activities, when, amongst other things, the summer meeting was revived as well as the annual dinner. During his year of office Cardiff was visited by two very important bodies with which their own Institute might be said to have a close affinity: he alluded to the British Association and the Iron and Steel Institute; and in regard to those visits Mr. Dyer Lewis worthily upheld the traditions of the South Wales Institute of Engineers. (Hear, hear.) They all knew that the time of the Divisional Inspector of Mines in a district like theirs must be pretty fully occupied; and he (the President) would not be surprised to learn that Mr. Dyer Lewis frequently found himself compelled to do what certain other people in South Wales of whom they knew refused to do, namely, to work double-shift—(laughter)—in order to attend to his duties of Institute President. Mr. Lewis's proverbial geniality and tact had made him a highly popular President, and they owed him a very cordial vote of thanks for what he had done.

Dr. H. K. Jordan.

Dr. H. K. Jordan said he had peculiar pleasure in seconding the motion of thanks to the retiring President. He had known Mr. Dyer Lewis since he was a student at Messrs. Brogden's works at Tondu, and knew his father and his brothers. For forty years or more he had followed the career of Mr. Dyer Lewis with interest, and had derived keen personal pleasure at his advancement step by step. He had filled the position of President of the Institute with dignity and geniality, and relinquished the duties of the office with the knowledge that he had done well. (Applause.)

The vote of thanks was adopted with acclamation; and Mr. Dyer Lewis briefly responded.

Scholarship for University College, Swansea.

The President.

The President announced that the Council had decided to grant a scholarship in engineering of £70 a year to the new University College, Swansea, tenable for three years, being a similar grant to that which had been made for a considerable period for a similar object to the University College, Cardiff. (Applause.)

Lewis Prize Award.

The President.

The President said the first Lewis Prize of £20 had been awarded to R. C. Morgan, Mountain Ash, for his paper on Subsidences and their Prevention. The second prize would not be awarded this year, the Council being of opinion that the other essays did not quite come up to the standard.

Election of Office-Bearers.

The following were declared duly elected office-bearers for the session 1921 :—

Vice-Presidents.

Mr. H. SPENCE THOMAS . . .	Cardiff.
Mr. THEODORE VACHELL, A.M.Inst.C.E.	Newport (Mon.).

Members of Council.

Mr. T. ALLAN JOHNSON . . .	Cardiff.
Mr. TREVOR F. THOMAS, A.M.Inst.C.E.	Whitchurch, Glam.
Mr. DAVID HANNAH . . .	Penarth
Mr. F. W. GILBERTSON . . .	Pontardawe.
Mr. EDMUND L. HANN . . .	Aberdare.
Principal GEO. KNOX, F.G.S. . .	Radyr.
Mr. D. F. DAVIES, F.G.S. . .	Cross Hands, Llanelly.

Election of Members.

The following candidates for admission to the Institute were declared to be duly elected :—

As Members.

BINKS, JOHN CHARLES . .	Duffryn Isaf, Nantgarw.
JOHNS, THOMAS . . .	Tynycoed House, Tonyrefail.
MITCHARD, FRANK . . .	Tonyrefail.

As Associate Member.

HAWKINS, WILLIAM JOHN MORTIMER . . .	Penarth.

As Associate.

COLLINS, HENRY EDWIN . .	University College, Cardiff.

East Glamorgan Association of Students.

The following members of the East Glamorgan Association of Students of the Institute, having been duly nominated by

Principal George Knox, Messrs. John Samuel and W. T. Lane, were declared to be duly elected :—

As Associates.

Arthur, Evan John . .	Abercanaid.
Bigge, J. H. Egerton .	Cardiff.
Bundy, William Payne .	Gelli-Pentre, Rhondda, Glam.
Hobbs, Henry . . .	Cardiff.
Holley, Harry . .	Cilfyndd, nr. Pontypridd.
Lewis, Haydn Price .	Clydach Vale, Rhondda.
Marshall, Henry Edgar .	Eastwood Park, Falfield, Glos.
Mesney, Roger James .	Cardiff.
Norris, Herbert T. . .	Cardiff.
Potter, Albert . .	Pontypridd.
Rosser, William Pryce .	Lanwood, Pontypridd.
Stroud, Percy L. . .	Brynmill, Swansea.
Watts, Edward Albert .	Treorchy, Glam.
Williams, Vivian . .	Trealaw, Rhondda.
Wright, Fredric Reginald	Cardiff.

As Students.

Davies, Gwynfor . .	Pwll, Llanelly, Carm.
Gibson, Harold Burnip .	Whitchurch, Cardiff.
Jones, Ernest Howell Andrew . . .	Treharris, Glam.
Nicholas, Harry . .	Wattstown, Glam.

President's Inaugural Address.

The President. The President (Mr. W. Forster Brown, M.Inst.C.E.) then delivered his inaugural address as follows :—

PRESIDENTIAL ADDRESS.

By Mr. Westgarth Forster Brown, M.Inst.C.E.

The President.

The difficulty of selecting a subject for a presidential address which may be of general interest to the members has been voiced by many of my predecessors in this chair, and I find myself no exception to the rule.

Man, after passing through a period variously estimated by geologists to have extended from 120,000 to 600,000 years, reached the Bronze Age about 4800 B.C. This age extended to about the thirteenth century B.C., when he entered upon the Iron Age, which has lasted to the present day. The use of iron in this country is said to have commenced between 300 and 500 years B.C.

When one contemplates the time which, according to these estimates, has elapsed and the progress which man has made since the days when he wandered over the face of the earth, dependent for his life and food upon his skill in utilising the rough stone implements, of which he has left us so many traces, one is struck by the fact that the rate of industrial progress has been materially accelerated in recent times.

Certain it is that the progress made in scientific and engineering knowledge during the past century and a half has been out of all proportion to that over the long vista of time extending back to the dawn of history.

If one is asked to give a reason for this great acceleration, are we not forced to the conclusion that it has been rendered possible by the general application of the heating properties of coal to engineering and industrial purposes?

It is certain that no such rapid development as has taken place in our own country during the past one hundred years would have been possible without the easily accessible stores of fuel in our great coal-fields, and the present age may as aptly be termed the Coal Age as that of Iron.

The President. The discovery of the elastic properties of steam, which was known as far back as 250 years B.C., remained practically useless to mankind until applied by Savery to the pumping of water about 1698. The inventions of James Watt about 1763 to 1769 brought the use of steam to a higher state of utility; but even these important inventions, together with the invention of the locomotive, with many others of general utility, made but slow progress before the time when the use of cheap coal fuel became general.

Although, therefore, I am addressing members of an institute comprising engineers of all branches, I need perhaps no excuse for taking as the subject of my address a cursory review of this country's present position relative to coal, touching at the same time upon some of the advances which have been made, and are being made, in connection with the production and safe working of coal at the present day.

Production.

The earliest estimate of an annual production of coal in Great Britain appears to date back to the year 1800, when 10,000,000 tons are said to have been raised.

Coal is said by some to have been an article of household consumption as far back as A.D. 852, but there is some doubt as to this. It is, however, fairly well authenticated that coal was being worked early in the thirteenth century. Between 1800 and 1865 the production of coal in the United Kingdom had risen to 98,150,587 tons, and by 1913, when the highest recorded output was reached, to 287,411,869 tons. The output in 1919 was 229,779,517 tons.

In the South Wales coal-field the earliest authentic record of annual output is in 1854, when 8,500,000 tons were raised. This by 1865 had risen to 12,656,336 tons, and to 56,830,072 tons in 1913. The output for 1919 was 47,522,306 tons.

The record output in South Wales in 1913 was equivalent

to 19·7 per cent. of the total output of the United Kingdom in that year. **The President.**

Although no reliable record of actual output in this coal-field exists prior to 1854, records of shipment exist as far back as 1745, when a total of 1,857 tons was shipped entirely from the western ports of Milford, Tenby, and Haverfordwest.

It may be of interest to note that the record of exports in 1828 in Wales amounted to a total of 904,896 tons, of which the port of Newport shipped 422,878 tons, Swansea 339,411 tons, Llanelly 92,144 tons, Cardiff only 32,109 tons, and Milford 18,354 tons. Between therefore the earliest record and this date, the chief exporting port had shifted from the extreme west to the extreme east of the coal-field.

If we consider the position of the United Kingdom relative to the world's coal production, we find that in 1865 the total output of coal in the world was estimated at about 182,000,000 tons, whilst in 1913 it was about 979,349,132 tons. In the earlier year, therefore, the United Kingdom produced approximately $54\frac{1}{2}$ per cent. of the world's production, and was by far the largest single producer of coal, whilst in 1913 its proportion had fallen to about 29 per cent. and it had to be content with second place, having been outstripped by the United States and closely approached by Germany.

Resources.

The very rapid increase which took place in the rate of production of coal in this country up to the outbreak of war in 1914, has from time to time given rise to feelings of alarm in the public mind lest we were exhausting our coal resources at too rapid a rate. I need not refer in detail to the several investigations which have been made from time to time—members are well acquainted with them—but will recall that the Royal Commission on Coal Supplies (1903–1905) brought out a total of one hundred thousand nine hundred and fourteen

The President. millions, six hundred and sixty-eight thousand, one hundred and sixty-seven tons (100,914,668,167 tons) as being probably available in this country, including seams of one foot in thickness and upwards, down to a depth of 4,000 feet from the surface. A quantity sufficient to maintain the maximum rate of output so far subsequently attained for well over three centuries. This total is, however, a comparatively small one when compared with the gross quantity (*i.e.* before making deductions for unworkable coal and that lost in working) estimated to be contained in the world as a whole.

The investigations carried out upon the initiative of the XII International Geological Congress, held in Canada in 1913, estimated a total, including all classes of coal, of 7,397,553 million tons, of which 189,533 million tons are allocated to Great Britain and Ireland. It may therefore be said that our country possesses round about 2½ per cent. of the total gross coal resources of the world.

It may be of interest to note the relative rate of output to gross estimated reserves in the three countries producing the largest annual output during 1913. It must, however, be remembered that a large deduction, probably at least one-third, must be made from the estimated gross resources to arrive at the quantity of probable workable coal.

	Reserves. Million Tons.	Output (1913). Tons.	Output (1919). Tons.
United States of America .	3,838,657	508,893,052	485,949,107
United Kingdom	189,533	287,430,473	229,779,517
Germany	423,356	274,264,420	199,152,934

If the question of reserves of coal in relation to the existing production was the only problem facing this country to-day in relation to its coal supply, we should not require to exercise our minds very acutely. A consideration, however, as to how much of these potential reserves we shall be able to produce at such an economical cost as will enable our many other industries to live in competition with those of other countries brings us

face to face with a more pressing problem, and one which the country will look to its mining engineers, colliery managers, and others engaged in the industry to solve. The President.

Cost of Production.

Unfortunately few official figures of the cost of producing coal in the different countries of the world appear to be available. From my own knowledge I should judge the cost of raising coal and putting it into truck in Australia to-day as not more than 12*s.* 6*d.* per ton. In South Africa the cost is likely to be considerably less. In Nova Scotia it is stated that the minimum cost is 18*s.* 8*d.* per ton, and the average will therefore be higher. In Spain several authorities give the cost to-day as round about 36*s.* 6*d.* per ton. From the reports received by the United States Federal Trade Commission, from 1,589 bituminous mines, the average cost of production in America in the month of January, 1920, is stated to have been 2·32 dollars per net ton of 2,000 lb. This figure does not include selling expenses, but is the cost of production at the mine. This cost is equivalent, at the rate of exchange in that month, to about 13*s.* 1·76*d.* per net ton, or 14*s.* 8·69*d.* per statute ton.

The cost of production in this country as a whole was stated officially to be 33*s.* 8·69*d.* per ton at the mine for the quarter ended June 30, 1920, for the September quarter 34*s.* 10·47*d.*, and will be higher now.

In comparing the year 1891, a year of high prices in the coal trade, with the present time, I should not perhaps be far wrong in saying that the cost of production in this coal-field has risen by over 300 per cent.

Indications are that the cost of production in the United Kingdom has risen and is rising at a more rapid rate than in many other countries. To the extent that this is so, and may continue to be so, must our industries be handicapped in the future in competitive markets.

Other Power Producers.

The President. Certain it is that the present scarcity of coal and the high prices which have to be paid for uncontrolled coal is stimulating the production of other classes of fuel, and is directing attention to other means of producing power.

The most important of these at the moment may be taken to be the use of oil in one form or another, and it may be of interest to glance at the figures relative to the production of petroleum in the world.

Messrs. Redwood & Eastlake give the world's production of petroleum as 22,160,701 metric tons in the year 1901, and as 43,989,568 tons in 1910. In 1919 the output had increased to approximately 85,327,584 metric tons, thus apparently about doubling itself every ten years.

Attempts have been made to arrive at an estimate of the quantity of oil reserves in the world, but with our present knowledge it is difficult to arrive at anything very reliable. Mr. E. Stebinger of the United States Geological Survey Department estimates 43 American billion barrels as being available in certain areas, whilst Dr. David White of the same department adds a further 20 billion barrels in areas not covered by Mr. Stebinger's estimate, making 60 billion barrels, equivalent to approximately 9,692,307,692 metric tons, as being probably available. Whether this statement can be taken to be reliable or not, a list of the most important oil-producing countries, in the order of their production in 1919, shows how widely oil is distributed in the world. The countries comprise the United States of America, Mexico, Russia, Dutch East Indies and British Borneo, India, Persia, Roumania, Galicia, Trinidad, Peru, Japan and Formosa, Egypt, Argentina, Germany, Canada, Venezuela and Italy.

It is not possible to say to what extent the oil reserves of the

world will be able to respond to the very rapidly increasing demand, but in view of the wide distribution of the resources already known, and the fact that many countries have as yet been but scantily explored, it appears undoubted that a considerably larger output than that at present produced will be found possible. The President.

As an indication of the increasing use of oil fuel for navigation purposes, the following figures, taken from Lloyds Register of Shipping Report, 1919–1920, are of interest :—

The total number of vessels classed in Lloyds Register of June 30, 1920, was 9,587, with a total tonnage of more than 25 million gross.

Of the world's total tonnage of vessels of 100 tons and upwards on Lloyds Register, an approximate division as to the fuel motive power is made as follows :—

For the year ending June, 1919 :

Using coal as fuel	82 per cent.
Fitted to use oil as fuel for boilers . .	10·5 per cent.
Using oil in internal combustion engines .	1·5 per cent.
Using sail power only	6 per cent.

For the year ending June, 1920 :

Using coal as fuel	76 per cent.
Fitted to use oil as fuel for boilers . .	16·3 per cent.
Using oil in internal combustion engines .	1·7 per cent.
Using sail power only	6 per cent.

It will thus be seen that during the period of one year oil has gained at the expense of coal 6 per cent. of the tonnage available.

Increased attention is being devoted to our peat bogs,

The President. with the object not only of producing domestic fuel, but of extracting oils and other by-products. The successful extraction of the latter upon a commercial scale is perhaps hardly yet beyond the experimental stage. It is scarcely probable that peat developments will in any way affect the demand for coal, except in very local and circumscribed areas.

Other methods of obtaining supplies of power independently of coal are also receiving increased attention. Perhaps the most important to which reference may be made is the possible utilisation of water-power resources available in our own country and in countries some of which are at present partially utilising British coal.

Two committees, one appointed by the Board of Trade and one by the Conjoint Board of Scientific Societies, have lately investigated this question.

It is estimated that the water-power resources of the United Kingdom are sufficient, excluding tidal energy, to develop continuously over 1,000,000 i.h.p. per annum.

Taking France, Italy, Iceland, Norway and Sweden, from estimates which have been made, it seems probable that the water-power resources in these countries are capable of developing not less than 24,000,000 h.p. How much of this is commercially capable of development has not yet been determined.

France has already in work, or in process of development, hydro-electric schemes capable of developing 1,600,000 h.p., Italy 300,000 h.p., out of a possible 2,000,000, and similarly in the other countries developments are taking place.

If we adopt an estimate of 3 lb. of coal burnt per i.h.p. per hour, as compared with 5 lb. stated by the Royal Commission on Coal Supplies (1903–1905) as being about the then average, and assume that the whole of the above power estimate is capable of commercial development, we arrive at a figure

of 281,571,000 tons of coal as being equivalent to the above total estimated h.p. capable of being produced by water-power in these countries per annum. During 1918 the countries enumerated imported 22,907,012 tons of British coal, and their total consumption amounted to 50,409,305 tons per annum. The President.

This estimate does not include power which might be produced from the energy of the tides. Members will recently have seen in the Press an account of the scheme prepared by the Ministry of Transport for the utilisation of the tidal waters of the Severn, by which it is estimated that 500,000 h.p. can be produced, with a maximum of 1,000,000 h.p. during certain hours.

The scheme is one which cannot but be of interest to engineers, involving as it does novel features designed to meet the undoubted difficulties which have to be faced in a project of such magnitude. It is scarcely possible, however, at the present stage to say whether this and schemes of similar nature will prove to be practicable forms of obtaining energy at a reasonable outlay and cost.

It would appear from the very brief summary which I have been able to give as to this country's present coal position that we may expect that so long as the cost of producing coal remains as it is at present, or rises higher, it will tend to lose ground as a direct power producer.

The extent to which this will take place will be dependent upon several factors; amongst them may be cited the capability of other forms of power production to meet the demand for them and the financial aspect in connection with finding the large sums necessary for the development of some of these other power resources.

The fact, however, that these other methods of obtaining power should be now receiving serious attention, coupled with the increasing consumption of oil as a power producer, are

The President. but indications that the present level of cost of production of coal in this country, and the price that other countries dependent upon imported coal have to pay, is closely approaching a limit which threatens industrial activity.

The present high level of cost of coal production in the United Kingdom has been brought about by causes outside the control of the engineer, *e.g.* the high rate of wages now paid, coupled with low production per person employed, shorter hours, and the higher cost of materials. Had it not been for the many improvements which have been carried out by those engaged in the coal industry in the past, the present cost would undoubtedly be higher than it is.

I do not propose to enter into the question of the abrogation of government control of the coal industry or of the mutual co-operation of capital and labour in accomplishing the above ends, except to express a hope that the good sense for which this country is noted may enable these very essential factors to be brought about to the benefit of all concerned, without which any improvements or economies which may be effected by the engineer will be rendered nugatory. Rather would I note in passing some of the lines of advance which have been made, and those which appear to be still open to those engaged in the management of collieries in their endeavours to arrive at the desired end.

In the problems connected with the economical production of coal, it must not be forgotten that the engineer has to deal with very varied physical conditions, and that improvements which promise well under one set of physical conditions may prove to be utter failures under others. It is by a just appreciation of what is practicable under the set of conditions with which the engineer is called upon to deal that his skill is best shown and good results obtained.

Turning firstly to underground mining conditions; the

The President.

getting of coal and the conveyance to the pit-top, when con-sidered from the point of view of economy in production, might be divided into : cutting and loading in the working face ; the naintenance of face roadways and filling of packs ; the main-enance of the main roadways, and transporting the coal rom the working face to the pit-top.

A colliery manager will always aim at improving his yield f coal per yard of working face or other unit per shift ; he vill aim at reducing the proportion which the unproductive ace-road maintenance bears to that paid for productive coal-getting ; he will endeavour to reduce the amount of power equired and the cost of producing and transmitting the iecessary power for transporting the coal from the working ace to the shaft bottom.

Considerable progress has been made in the mines of the Jnited Kingdom during the past twenty years in the application f mechanical coal-cutters, with the object of obtaining a larger ield of coal per yard or other unit of working face per shift. The number of such cutters at work in 1900 was round about 20, and in the year 1919, 4,482 ; 28,081,017 tons of coal being nechanically cut in the latter year, or 12·22 per cent. of the otal output raised.

It is interesting to note that Mr. Menelaus, that far-seeing nan, one of the founders of this Institute and its first President, n his presidential address in 1858 foresaw the possibility of utting coal mechanically, provided some flexible means of onveying power long distances underground was discovered ; e refers to the use of compressed air, at that time in its infancy, s a possible means of enabling this to be done. Since that ime this form of power transmission has been vastly improved nd turned to account in hauling, pumping, drilling, and nechanical coal-cutting, and we now have electric transmission n addition.

The President. The physical condition under which many of the seams in the South Wales coal-field exist militates against the successful general adoption of mechanical coal-cutters. This is reflected in the slow increase in the number in use, which in 1900 was 7 and in 1919, 182; the tonnage cut mechanically in 1919 being 897,047 tons.

It may be well to note that an output closely approaching to the record output so far raised in the United Kingdom was mechanically cut in the United States in 1916 by means of 16,197 machines, being approximately 56½ per cent. of the total output of that country in that year.

There would therefore appear still to be a margin in this country for a more extended use of coal-cutting machines.

The extension of the use of mechanical face-coal conveyors offers a hope of materially reducing the proportion which the cost of maintenance of face roadways bears to the cost of productive coal yield, by lessening the number to be maintained relative to the length of coal faces. That colliery managers are alive to the advantages to be gained by their use can be judged from the increasing number in use in the United Kingdom. The number employed in 1909 was 177, and in 1919, 712; but much, no doubt, can still be done in this direction. In the South Wales coal-field the number of conveyors in use in 1919 was 285, showing a larger number than in any other district. The use of conveyors together with mechanical coal-cutters, where the conditions are favourable, appear at present to be the most promising engineering means of reducing cost in the working faces.

The successful maintenance at a reasonable cost of the roadways at deep collieries in this coal-field is perhaps one of the most troublesome problems facing the colliery engineer. As is well known, the crush to which the strata is subject in

our deep pits is very great. It has been suggested by some that the adoption of some form of hydraulic stowing would be advantageous. The President.

It is undoubtedly true that this method of stowing the underground wastes, where suitable material is available, considerably reduces the subsidence of the strata overlying the packs, and to that extent would tend in the direction of the better maintenance of underground roadways and lessen the subsidence of the surface overlying longwall workings. Against this must be set the risk, in the steam-coal strata of this coal-field, that the water which must necessarily be used in the operation would cause the floors of the roadways to heave to an extent sufficient to counteract, if not outweigh, the saving to be effected by tighter packing. There is the added difficulty in this coal-field of finding suitable material in sufficient quantity. I recall that some years ago the employment of this system, by utilising washery refuse upon certain main roadways of a colliery in this district, was seriously considered. The fear, however, that after a large capital outlay had been incurred, the difficulty already alluded to of keeping the roadways open would arise, caused the idea to be abandoned.

A test of the system carried out under agreed bad conditions of roof and floor, if successful, would do much to remove the existing doubt as to the possibility of employing it under the conditions of our steam-coal measures, and perhaps lead to its adoption so far as suitable material is available for a width along some of the main roadways, with a view to their better and cheaper maintenance.

In the meantime it is satisfactory to note that some progress is being made in controlling the heavy crush met with in some of the shaft mouthings of some of our deep collieries in this coal-field.

The President. Twenty years ago it seemed somewhat problematical as to whether it was possible to build shaft mouthings in deep collieries by arching or otherwise which could be looked upon as permanent, in view of the heavy crush to which they were subjected. It has, however, now I think been fairly conclusively proved at several of our deep collieries that this is possible by the employment of strong arch-girders backed with ferro-concrete, although at considerable outlay.

With our present knowledge the extension of this class of heavy ferro-concrete arching to the ordinary main roadways of a colliery does not seem practicable, both on account of the expense entailed and the doubt whether even work of this strength would stand where a general subsidence of the strata is going forward ; but there seems much to be said for the extension of the system of light rail arch-girders backed with light brickwork between. Experience seems to show that this method of securing the main roadways stands on the whole better than timber or ordinary arching, forms a safe roadway, and one more easily kept free from coal-dust.

The cost of transporting the coal, often long distances from the working face to the pit-top, forms a substantial proportion of the cost of production. Over the past twenty-five years the tendency has been to increase the weight of the rail used upon the main underground roadways and to improve the design and lubrication of the trams, with a view to minimising the power required in hauling.

The much extended use of compressed air for the purposes of hauling, pumping, and other purposes underground has led to much improvement in the efficiency of compressed air-power plant. The original simple steam-driven slow and high speed compressors, compressing air to 50 lb. per square inch pressure, have given way to compound steam slow and high speed compressors, or electrically driven high speed com-

pressors compressing the air in two stages to pressures of 80 to 100 lb. per square inch. The President.

Electrical power has also been largely applied for operating underground hauling engines and pumps, in mechanical coal cutting and in lighting. The original direct current installations have largely been replaced by those operated by alternating current, and the small voltages, 100 to 500 volts, at first in use underground, have, where circumstances allow of it, been replaced by higher voltages of as much as 2,000 to 3,000 volts. In many collieries, however, it is usual to limit the pressure of the underground electric current to 500 volts.

In many of the collieries of this coal-field, owing to the fiery nature of the seams, the employment of electric current as a motive power near the working faces is inadmissible. In this connection I might call attention to the new method of power transmission known as 'Wave Transmission' or 'Sonic Transmission' as developed by Messrs. W. H. Dorman & Company, Ltd., from the invention of Mr. George Constantinesco, which should prove one of interest to the mining engineer and colliery manager, offering, as it appears to do, an alternative method of power transmission in our collieries and metalliferous mines to the five now in use, viz. steam, direct mechanical, electrical, compressed air, and hydraulic.

As you are all no doubt aware, this method of wave transmission depends for its application upon the basic principle of the elasticity of liquids, and broadly consists of setting up wave motions or pulsation in some liquid by the action of a plunger. These pulsations are communicated through the liquid to plungers at the other end, synchronising in their action with the originating plunger. No transference of the liquid takes place, the pulsations only being communicated to the operating plunger.

The President. The inventors claim for their system of applying this method of power transmission a saving of 80 per cent. in mechanical efficiency, considerable saving in capital outlay, and other advantages as compared with modern compressed air plant; and if in practice these claims can be substantiated, the system offers a hope of substantial economy in the transmission of power to long distances in our collieries, especially in cases where electrical transmission is not admissible.

At the present time this system is being applied to the driving of shop tools and rock drills, and the number of industrial applications to which it might be applied is hardly less than those now operated by other forms of power transmission.

There is perhaps an interest attached to this method of power transmission outside the simple practical one, as it would appear to approach more closely than any of the other systems to the probable basic method by which energy is transmitted throughout the universe.

In underground pumping the most noticeable feature during the past twenty years has been the introduction of the high speed turbo-pump, driven direct by steam turbine or electric motor. Large quantities of water are now economically raised by this means against high heads, the number of chambers in the pump being designed to meet the head to be dealt with.

In this connection one must not omit to refer to the part played by the introduction of the process of cementation, largely developed by Monsieur François in dealing with some of the difficult problems in mining due to the presence of excessive quantities of water. Many of you will have read Mr. Standish Ball's interesting paper [1] read before this Institute a few weeks ago, and which brings home to us the many and varied circumstances under which this process has been successfully employed.

[1] Vide *Proceedings*, Vol. 36, No. 2, p. 511.

The tendency in ventilation has been towards the employment of high water gauges up to 6–8 inches as compared with $1\frac{1}{2}$ to 2 inches common twenty-five years ago. The progress made in electrical practice has enabled high speed fans of comparatively small diameter to be utilised in place of the large diameter fans previously in use. **The President.**

The ventilation of our deep mines and the maintenance of the wet-bulb temperature at a reasonable level, so as to avoid any hindering effect upon the men's work when the depth becomes very great, is another problem which may call for solution in the future. The conclusions so far come to by the committee appointed by the Institution of Mining Engineers to consider the control of atmospheric conditions in hot and deep mines, would seem to indicate that at depths of coal mining at present contemplated in this country it is possible by a well-designed system of ventilation and avoidance of leakage to prevent an excessive rise in the wet-bulb temperature. It may be noted, however, that it has been found necessary at Morro Velho Mine in Brazil, owned by the St. John del Rey Mining Company—I believe the deepest mine in the world—to adopt special methods of cooling the air entering the mine. The lowest workings in this mine are at a level of 6,400 feet, or nearly $1\frac{1}{4}$ miles from the surface, and the problem which the proprietors were called upon to face was the reduction of an initial wet-bulb temperature varying from 72° to 43·5° F. at the surface, so as to arrive at a wet-bulb temperature not exceeding 85°F. in the stopes or underground working places. This is to be accomplished by extracting by refrigeration 100,000 British thermal units per minute from an air-current of 80,000 cubic feet per minute. Owing to the great variation of the surface wet-bulb temperature at the mine, the refrigerating plant is divided into six stages to meet the varying load upon the plant.

Doubtless when it becomes necessary to deal with this

The President. question at dry collieries in this country the problem will be solved upon some such lines as those now being adopted in the above mine. The difficulties attending the adoption of the process at collieries would seem to lie in the direction of the magnitude of the operation, in view of the large air-currents requiring to be cooled.

Economies at the surface have been and are being directed with two objects in view, viz.:

1. Reducing the cost of production and economising the utilisation of the power required in the production of coal.
2. Improvement in the value of the product by efficient screening and washing, and, where the coal is suitable, coking and the extraction of its by-products.

The more general introduction over the past twenty-five years of Lancashire and Multitubular Boilers generating steam at a high pressure up to 200 lb. per square inch, fitted with economisers and in some cases superheaters, has enabled steam to be generated more efficiently than was the case in the egg-ended type of boiler common twenty-five years ago. The adaptation of the fire-grates to enable inferior fuels to be burnt has also progressed, and it would seem that inferior grades of fuel, which may otherwise be left in the mine or sent to the rubbish tip, may either be burnt under boilers or in refuse destructors; and further economies may be possible if the difficulties of economically handling the large amount of incombustible material contained in them can be overcome.

Mechanical stokers, although frequently adopted, have not become general. By their use it has often been found possible to increase the evaporative performance of the boiler, and in some cases it has enabled inferior fuel to be burnt.

The adoption of a compound engine for winding purposes

has not become general, possibly indicating that the ordinary high pressure steam engine is a fairly efficient machine for the purpose for which it is used, and that the economy to be gained on the short intermittent runs of a winding engine is not sufficient to induce a general replacement of existing high pressure winding engines. The President.

The most noticeable feature in winding over the last quarter of a century has been the application of electrical power for this purpose. Two main types of these winders have so far been devised: those working in conjunction with an equalising set, comprising either an AC or DC motor driving a heavy fly-wheel in which energy is stored up, and upon which the winder makes demand at times of peak load, thus lessening the maximum demand upon the supply mains, and, secondly, winders which are operated direct from the supply mains in which the generating station is required to meet the full load.

The suitability of one or other type and its several advantages and disadvantages to meet particular sets of conditions are still open to much discussion, as also is the question as to whether it is preferable to have a slow rate of wind with heavy useful load or a rapid rate of wind and a less useful load. Examples of both types of winders and both slow and rapid winding are to be seen in this district.

The even acceleration, which is a feature of the utilisation of electrical power, gives a steadier ride of the cages in the shaft than a steam winder, and is therefore an advantage in deep shafts where the use of rope guides is contemplated.

Where steam is employed the higher pressures now in use have enabled much economy to be made in the various more or less continuous running steam engines about collieries; these are now very generally compounded.

Where waste steam is available much economy has been effected by the employment of low and mixed pressure turbines,

The President. utilising the waste steam and used to drive dynamos for generating the electrical power for operating all the small plant about a colliery, and thus doing away with numerous steam pipe ranges with their consequent loss of power.

The necessity of working thinner and dirtier coals has caused a general improvement in screening and sizing of coals. Belt-screens are now general, and enable the foreign matter to be more readily separated from the coal. This has enabled the product to be put upon the market in a much improved state compared with what was done some years ago, and has enabled users of coal, *i.e.* before government control came about, to make use of the class and size of coal which their experience taught them gave best results in their particular operations.

It has now become very general to wash coals below a certain size, and much thought and experiment have been expended upon devising efficient washing machines for this purpose. The principle of these machines, as you are aware, depends upon separating the particles of coal from the foreign material intermixed by reason of their different specific gravities. Many of the types of machines in use are quite effective in washing coal down to sizes of one-twentieth of an inch, but not below.

Recently a new development has become possible in dealing with particles of coal down to one-hundredth of an inch by the application of the Froth-flotation process to the separation of coal.

The principle, as applied by Mr. Draper of the Rhondda Engineering Company, as described in his paper on "The Draper Washer,"[1] has been found to efficiently separate and wash the smallest particles of coal, and thus render of considerable value what was once little more than a waste product. A machine of this type has been at work at the Llwynypia Collieries since May, 1917, and several others are now either in operation or in course of erection.

[1] Vide *Proceedings*, Vol. 34, No. 3, and Vol. 35, No. 1.

The coking of the small coal produced, where of suitable quality, and the extraction of its by-products have made rapid progress, especially during the past few years. **The President.**

By-product recovery coke-ovens are now responsible for the production of the largest proportion of the metallurgical coke in this country. The following figures taken from Dr. Hatch's interesting review of the work of the Ministry of Munitions during the war period are of great interest as showing the rapid manner in which this modern form of coke-oven is replacing the older form of non-recovery coke-oven.

In 1918 the total consumption of metallurgical coke in the United Kingdom was 12,667,000 tons, of which 80 per cent. was produced at by-product recovery ovens, 16 per cent. at beehive ovens, and 4 per cent. at Coppée retort non-recovery ovens. In 1913 only 58 per cent. of the coke output was obtained from by-product ovens.

In October, 1918, there were 8,375 by-product ovens in operation, 1,334 retort non-recovery ovens, and 6,399 beehives. The reduction of the number of beehive ovens from 13,167 in 1913 to 6,399 in 1918 resulted in the same amount of coke being produced with 800,000 tons less of coal per annum carbonised.

Such striking figures of the saving to be effected by the employment of the modern by-product oven as compared with the old beehive non-recovery type cannot but tend to hasten the conversion to the more efficient type.

In this district by far the larger proportion of the coke ovens in use are now of the latter type, although the yield of by-products per ton of coal carbonised is less favourable than in many coal-fields.

The recovery of by-products at colliery coke-ovens in this country is, excepting in a few instances, confined to sulphate of ammonia, crude benzol, tar and pitch, the waste gas being

The President. utilised for raising steam under boilers, or in gas engines used to drive dynamos for the generation of electrical power, the further distillation of tar products being usually carried out by separate manufacturers.

In view of the comparatively good illuminating power of coke-oven gas it has in some cases been possible to dispose of the waste gas to local authorities for the purpose of lighting. This tendency, where opportunity offers, is likely to find considerable extension in the future.

In Germany it appears to be the practice to carry the distillation into great detail and to produce a number of the useful tar products at the colliery. Doubtless the colliery owner in this country will find it in future profitable to follow upon these lines.

Much experimental work has been carried out during the past few years in attempting to produce a smokeless fuel and such by-products as can be obtained from coal when subjected to comparatively low temperatures of from 400° to 700° C. It seems probable that within the next few years a considerable development of these processes will be seen.

In the foregoing remarks a cursory view has been taken of some of the improvements which have been effected by those engaged in the coal industry in dealing with the practical problems relative to the economical production of coal.

This address would not be complete without a passing reference to those other problems which are always before them, and to which an immense amount of thought, experiment, and outlay have been devoted. I refer to problems connected with the safe working of coal and the endeavours which have been made, and are being made, to lessen the number of fatal and other accidents which, from the nature of things, appear to be incident to the calling of coal-getting.

Very much has already been done in the way of prevention

of such accidents, as can be judged from the following figures taken from H.M. Chief Inspector of Mines Report for the year 1919, Part I.—Divisional Statistics and Reports.

The percentage of death-rate per 1,000 persons employed, taking both above and underground, in the decennial period from 1873 to 1882 averaged 2·24; this for the decennial period 1903 to 1912 has been reduced to 1·33, and for the year 1919 this figure has come down to ·94. If we take the figures per 1,000,000 tons of minerals raised the corresponding figures are 7·43, 4·76, and 4·67 respectively. A satisfactory feature is that the decline in the death-rate applies under each heading under which accidents are recorded, and is a cogent answer to the unjustifiable statements sometimes made that those who own and control the coal working in this country are not conscious of their responsibilities in this respect.

The greatest single cause of fatal accidents is due to falls of roof and sides. The larger number of these accidents in this district occur in the working face, where the highest proportion of workmen are congregated.

Every practical man will, I think, agree that one of the best safeguards against falls of roof in the coal face is to keep the working faces, when working upon the longwall system, advancing as rapidly as possible, so that the collier is working as much as possible under what is termed 'green roof,' *i.e.* roof which has not had to stand open long supported on timber before being underpinned with the advancing packs; this, coupled with careful timbering by the collier himself, appears to offer the best chance of lessening this class of accident. The present reduced production of coal per man, entailing as it does the slower progress of the working face, from whatever cause arising, is not conducive to increased safety to the worker in the coal working faces.

The prevention of gas and coal-dust explosions, and the

The President. doing away with the terrible accidents resulting therefrom, have been the aim and object of mining men and others for half a century and more. I need not recapitulate the numerous inquiries and series of experiments on this question which have been carried out, both in this country and others, by governments, coal-owners, and others ; these are well known to you.

The safeguards at present available against explosion may be stated to be adequate ventilation to prevent, if possible, the accumulation of fire-damp ; the employment of the best forms of safety-lamps ; the restriction and regulation of shot-firing, and the keeping of roadways as far as possible free from coal-dust.

Improvements which have taken place in relation to oil safety-lamps during the past twenty-five years have been largely in the direction of improved light, the main principle remaining as originally devised by Sir Humphry Davy.

Electric accumulator lamps are now common in the mines of this country, and although their cost of upkeep is greater than that of the oil lamp, the increased light which they give is found to be of advantage.

The danger lurking in the coal-dust which lodges on the floor, roofs, and sides of the roadways of a mine is now generally recognised. Much has been done to regulate the use of explosives in collieries. These regulations are aimed at the utilisation of explosives which are rapid in their action and give little flame, with the view of minimising the risk of accidental firing of gas or coal-dust in the neighbourhood of a shot. The practice of watering the main roadways of collieries in this district, as a safeguard against the spread of an explosion, has been in use in some collieries for the past thirty years, but was first made compulsory in 1911.

Of late much information has been obtained as to the nullifying effect of the employment of stone-dust upon the

roadways of a colliery in preventing the ignition of coal-dust. In this connection members will recall that Mr. C. D. Budge, a member of this Institute, communicated much useful first-hand information in his excellent paper entitled 'Notes on the Stone-Dusting of Steam Coal Collieries,'[1] for which he was awarded the President's Gold Medal. The President.

Under the existing regulations which came into force on January 1 of this year, it is provided that the roof and sides of every roadway or part of a roadway shall be so treated with incombustible dust as to ensure that the dust on the floor, roof, and sides throughout shall always consist of a mixture containing not more than 50 per cent. of combustible matter, or alternatively shall be treated with water in such a manner as to ensure that the dust on the floor, roof, and sides is always combined with 30 per cent. by weight of water in intimate mixture.

The careful carrying out of the regulations which are deemed necessary, coupled with good supervision, are at the present time the practical steps available for limiting or doing away with this class of accident.

Whether the time will ever come when it will be possible to control and prevent the explosive chemical action which takes place in a gas or coal-dust explosion by chemical or physical means, it is hard to say. It is certainly difficult at present to see any possible practicable method by which this may be brought about. I, however, would like to call attention to certain features of this question, as it is a subject to which I have given a good deal of thought. In doing so I would make it clear that my remarks must be taken as suggestions as to possible lines of investigation in attempting to trace the causes underlying the initiation of an explosion, and not in any way that any statements made have been proved.

[1] Vide *Proceedings*, Vol. 32, No. 2, p. 203.

The President. The close connection existing between chemical and electrical action appears to be increasingly evident as our knowledge extends, and it does not seem improbable that the strain which causes the combination of molecules and atoms of different substances in chemical action may be of electrical nature.

The well-known chemist, Berzelius, who lived in the early part of the nineteenth century, had a theory that hydrogen and oxygen only exploded because of their charges of electricity, and that if they could each be got to take a charge of similar sign they would no longer explode. This theory is said to have been disproved.

With the knowledge which has since become available through the researches of the late Sir Wm. Crookes, Sir J. J. Thomson, Sir Oliver Lodge and many others, upon the electron as forming the minutest particle of matter, and when in a free state always carrying a definite charge of negative electricity, the question of electrical strain as being the cause both of gradual and sudden chemical action is perhaps worthy of further attention.

The determination of the actual value of the electric charge upon the electron, first carried out by Sir J. J. Thomson, supplies a basis to work from.

It was held a few years ago that the mass of an atom of an element would be due to the number of electrons contained in it. This conception has now given place to one in which the atom is thought to be comprised of a central nucleus of positive electricity, in which the greatest proportion of its mass is concentrated, surrounded by comparatively few electrons.

Under the older conception, however, that is, considering the atomic weight of an element as being an indication of the relative number of electrons contained in it, it is curious to note that if the possible electronic charge upon the two elements

combining in an explosion of fire-damp and air is calculated upon some unit quantity of the mixture, and taking, say, an explosive mixture of 10 volumes of air to 1 of fire-damp, we arrive at enormous figures of the strain which might exist between the two elements. If a similar calculation is made going down the scale approaching the limit at which it is not possible to get an explosion, we approach a point at which the charge on both the elements becomes more nearly balanced. The President.

Is it not possible, therefore, that the total electronic charge upon each element only becomes effective when certain forms of stimulus are applied? Such a supposition presupposes that one element will be electrified positively and the other negatively.

When, however, we consider that each element possesses in its light spectrum a different average oscillation frequency to any other element, and that this is likely to hold good in the invisible parts of the spectrum, is it not within the bounds of possibility that one day we shall find that what we differentiate to-day as positive and negative electricity will be explained in terms of the relative speed of vibration or rotation of the molecules or atoms of different elements to each other about a point of equilibrium; and that when two substances are out of equilibrium and show a charge of electricity, one will always be positive to the other? However this may be, we unfortunately are well aware of the enormous potential forces which are locked up in an explosive mixture, and which lie dormant until such time as the necessary stimulus is applied.

In the case of an explosion of air and fire-damp this stimulus is supplied by the application of a sufficiently high temperature communicated to the mixture by the application of flame or other incandescent substance.

It seems necessary, before any progress is possible beyond this point, to understand what exactly is the action of the

The President. stimulus—in this case flame—in creating or bringing to life the enormous strain between the combining elements.

We should say to-day that the application of flame heats up the mixture, and that it requires a certain temperature to cause an explosive combination. This does not carry us very far. We want to know something more as to the actual method in which the flame, or the heat generated by it, acts upon the molecules and atoms of the gases involved.

The writer would like to refer to an experiment which he carried out some time ago in conjunction with Mr. D. A. E. Evans, at one time a member of this Institute, not as necessarily novel or proving anything definite, but as suggesting perhaps a line of investigation as to the method by which radiant energy may act upon matter.

Over a tank of water a wooden bridge was fixed ; upon which two exactly similar small electric motors were fixed so that their axes were vertical and projected through a slit in the wooden bridge towards the surface of the water ; to the axes of the motors similar sized paddles of similar shape were fixed. A spindle was fixed at a point between the two motors, and two similar sized grooved pulleys, set horizontally, were fixed loosely to the spindle. These pulleys were marked in such a way that it was possible to see when they were revolving at exactly the same speed, and were driven by elastic bands from small pulleys on the shafts of the motors. The current to operate the motors was taken from two similar 4-volt accumulators—one to each motor—and led through similar resistances. In the case of one of these resistances, one end was connected to a double vertical coil of copper wire, in the centre of which was suspended a magnetic needle, forming a tangent galvano meter.

It was found that when the two motors were running, the needle of the galvanometer was deflected to show the current

passing, and when they were in synchronisation (as seen from the synchronisation of the horizontal pulleys), the current required as indicated by the tangent galvanometer was less than when not in sychronisation. The President.

It was also found, using one motor with galvanometer attached by moving the bridge towards the side of the tank so that the waves given off by the paddle would be deflected back upon it half a wave length behind, and thus interfering with the waves thrown off by the paddle, that a greater current than what may be termed the normal was required to keep the motors running at their full speed.

If these experiments are reliable, as the writer believes them to be, a good deal can be reasoned from them.

Do they not suggest that if matter is vibrating or rotating under constant power, that it is possible that radiant energy, whatever its source may be, acts by way of synchronisation and interference with the vibrations thrown off by particles of matter, thus increasing or decreasing the speed of vibration or rotation by reason of the constant power keeping them in vibration or rotation, and thus creating the varying strains which bring about chemical action either suddenly or slowly?

It seems to me to suggest possibilities of the way in which the sun's rays act in promoting the growth of plant life, and in the case we have been considering a possible method by which the strain between elements capable of explosive combination is brought about by the application of flame.

The experiments carried out by Professor Bose, which clearly show that the least disturbance of equilibrium of the molecules in plants or of metals by the application of stimulus produces an electric current, rather suggests that these strains when created are electrical in their nature.

If radiant energy acts upon matter in the way indicated, it may be that at some time in the future, when we have learned

The President. how to control the vibrations given out by matter, we shall be able to regulate its vibrations or rotations at will, and promote or prevent the consequences of the application of heat to explosive mixtures or in the slower action of spontaneous combustion—scientific problems to which the mining engineer and others interested in the working of coal are to-day giving a good deal of attention. Perhaps, however, when this comes about we shall be near the time when we shall be able to derive energy direct from matter, and the paramount position which coal holds to-day in the world as the producer of power will be near its eclipse.

Vote of Thanks to the President.

Mr. T. H. Deakin.

Mr. T. H. Deakin (a Past-President) said he rose with great pleasure to propose a very warm vote of thanks to the President for his very valuable and informing address. It had been the good fortune of that Institute for many years to have—at any rate with one exception, himself—very able men to occupy the presidential chair, but he ventured to say that they had very few presidents, if any, who surpassed the father of the present president in the ability and wide range of knowledge he displayed both as president and in the papers he submitted to the Institute from time to time. Mr. T. Forster Brown's papers on the South Wales Coalfield, written many years ago, were text-books to-day, and would probably remain text-books for all time. It was most gratifying to the members of the Institute to see the son of such a man occupying the position which his father held with so much distinction; and they recognised that in Mr. Westgarth Forster Brown they had the worthy son of a worthy sire. (Applause.)

Mr. J. Fox Tallis.

Mr. J. Fox Tallis (a Past-President) seconded the motion of thanks to the President. He said the address was one of

the most interesting and informing they had heard for a long time. He thought perhaps the most important part of it was that which dealt with the cost of coal production. They all knew that that cost was abnormal, but the President did not tell them how they were to reduce it. He often thought it was a mistake that by the rule of the Institute the President's inaugural address was not open to discussion. Not that there was anything controversial in the address to which they had just listened with so much pleasure and profit; but there were points in it upon which, if the address was open for discussion, members might be able to furnish additional information. In a friendly chat he once had with a miner's agent he told that official if he was allowed to work the coal, as he thought best he could do it more cheaply and there would be a larger margin from which to pay colliers' wages. His reply was, 'Our wages are based upon the selling price of the coal and our object is to make that price as high as possible so that the employers cannot sell it cheaply and pull down wages.' One of the causes of high cost of production was the increase of the item for dead work. Another cause was, of course, the decreased output per man. The miners believed that the smaller the output the higher would be the selling price; and this was the origin of the ca'-canny policy. By their tactics the workmen had upset the old theory of supply and demand; what they had now to demonstrate to the miners was that it was to their interests to work the coal as cheaply as possible, and thus provide a wider margin of profit from which to pay good wages. The mine manager might do his utmost to reduce costs of working by the introduction of machinery, but the attitude of the men to these mechanical innovations was notoriously hostile. **Mr. J. Fox Tallis.**

Mr. J. Dyer Lewis put the vote of thanks to the President, and it was cordially endorsed by the meeting. **Mr. J. Dyer Lewis.**

The President.

The President, in response, said he was afraid he had taxed their patience to the point of weariness by the length of his address—(' No, no ')—but if he had brought anything forward to stimulate thought he should feel satisfied.

Mining Warfare.

By Capt. D. Ivor Evans (late R.E.).

(Paper, *vide* Proceedings, Vol. XXXVI., No. 2, p. 385.)

Commenting upon this paper, Major W. P. Abbott said he had been particularly interested in reading Capt. Evans' valuable record of the tunnelling companies during the War. It might interest members to know that the first mining done by the army in France was very largely carried out by Monmouthshire men. He referred to the tunnelling at Hill 60 (Ypres). Forty members of the 1st Monmouthshire and forty members of the 3rd Monmouthshire, with their officers, were sent to Hill 60, with a field company of Northumberland Engineers. Afterwards some men came from London whose experience in constructing sewers was deemed a qualification for tunnelling. A member of that Institute, Colonel Robinson, H.M.I.M., at that time—March 1915—was offered control of the whole of the mining operations in France; he (the speaker) was in a room at Ypres when the offer was made; but Col. Robinson preferred to remain with his battalion, the 1st Monmouthshire, and a few months later made the great sacrifice, like the gallant gentleman he was. Such, then, was the first mining operation carried out in the war by Monmouthshire men, who were officered by members of the South Wales Institute of Engineers. (Applause.) **Major W. P. Abbott.**

The President said they would now close the discussion. The admirable record prepared by Captain Evans did not **The President.**

The President. lend itself to discussion, because it was a history of events, especially interesting to those whose privilege it was to serve in the War, and to undertake the hard and hazardous but exceedingly important work which fell to the lot of the tunnelling companies. It was very appropriate that such a paper as this, with its valuable record, should be permanently incorporated in the Institute's 'Proceedings.' He had pleasure in proposing the hearty thanks of members to Captain Ivor Evans. (Applause.)

The Outburst of Gas at Ponthenry Colliery.

By George Roblings.

Paper, *vide* Proceedings, Vol. XXXVI., No. 2, p. 423: Discussion on p. 432.

The President. The President said Mr. Roblings' paper was an interesting and a useful one, and calculated to prompt other members to describe their experiences of similar occurrences. He regretted that Mr. Roblings was unable to be present at the meeting.

Mr. J. Dyer Lewis. Mr. J. Dyer Lewis hoped the paper would be held over for another meeting, which would probably be attended by the author and also by a gentleman who would describe the outburst at Tareni Colliery, to which he (the speaker) referred at the last Swansea meeting of the Institute. As he had pointed out on that occasion, these outbursts usually occurred where a large disturbance had taken place. Curiously enough, the roof was not interfered with in any way; it was a thinning or thickening out of another part of the seam. The outburst was one of pulverised dust; and in this instance thousands of tramloads of dust were removed before the seat of the outburst could be reached. A point raised in the discussion at the Swansea meeting had reference to the type of

lamp used. The chief method of lighting at Ponthenry Colliery —as he had stated on a previous occasion—was by oil safety lamps. Had these lamps not given early indication of gas he feared that few men would have got away and escaped suffocation by the dust. All the lamps at Ponthenry were extinguished in the firedamp, which swept through the whole colliery right from the seat of the explosion to the return airway. As he had already suggested, where the electric lamp was generally used in the mine, the safest plan was to have oil safety lamps placed here and there along the face. Another point was that referred to by Mr. C. A. Seyler, who had stated that there was an excess of oxygen in this particular small coal which he had analysed. This was a new point, as far as he (Mr. Lewis) was aware, in regard to anthracite coal. Mr. J. Dyer Lewis.

Sir LEONARD LLEWELYN asked whether the outburst at Ponthenry Colliery occurred in a virgin area. Members would recall the outburst that took place in the earlier stages of the opening out of the Newport-Abercarn Co.'s Celynen Colliery. It was worked at the start on the pillar-and-stall system. In advancing the narrow headings the men forced the ribs too much, with the idea of getting a greater quantity of coal out of the centre; there was an outburst of gas filled with clouds of dust, the dust burying two men, a horse, and a tram. Very many trams were filled with the pulverised coal before the men and horse were recovered, although the distance from the tram to the face when measured afterwards in comparison to the amount of pulverised coal which had been carried away was comparatively small. The gas filled the whole district for at least twenty-four hours. This and other outbursts were attributed, he believed, to the tapping of virgin areas; and it would be interesting to know if this was the case at Ponthenry. Sir Leonard Llewelyn.

Mr. WILLIAM JOHNSON stated that from his experience these outbursts occurred in approaching a seam of coal that Mr. William Johnson.

Mr. William Johnson. was abnormally soft and thick. He had found similar conditions to those at Ponthenry, the coal at the outburst being in a pulverised state, and abnormally thick—some nineteen feet. The seam was fiery but not exceptionally so; neither was the district a virgin one.

Sir Leonard Llewelyn. Sir LEONARD LLEWELYN said so far as the case of the Celynen Colliery was concerned there had been no disturbance, such as faults, etc., in that particular area. The gas from the outburst traversed the workings and put out the lights. Had there been electric lamps it is possible that a good many of the men would have been smothered by the gas, as they would have had no warning from the lights.

Mr. J. Dyer Lewis. Mr. J. DYER LEWIS said so far as he recalled the conditions at Ponthenry the district affected was not virgin, but that seams had been worked above. A curious feature of this outburst was that for about a fortnight previously 'pinholes' or spurts of dust issuing from the coal, or 'blowers' as they were called, were reported to the fireman. The coal was quite hard up to the moment the outburst took place.

Mr. T. Greenland Davies. Mr. T. GREENLAND DAVIES pointed out, with regard to the type of lamp used, that the record of Ponthenry Colliery showed that all the oil safety lamps were extinguished by the gas. He was wondering how the men got out of the mine in the dark. They would certainly have got away more easily with electric lamps. Again, if none but electric lamps were used, could colliers be said thoroughly to examine their working places, according to the Regulations under the Coal Mines Act?

Sir Leonard Llewelyn. Sir LEONARD LLEWELYN: You are bound by the regulations to have one oil safety lamp in twenty.

Mr. T. Greenland Davies. Mr. T. GREENLAND DAVIES: I know of no such regulation.

Sir Leonard Llewelyn. Sir LEONARD LLEWELYN: Then there ought to be such a regulation.

Mr. W. D. Woolley said he wished to support Mr. Dyer Lewis's suggestion that this discussion be adjourned to enable other members to relate their experiences. He had a case in mind where an outburst of gas occurred, and although it was a virgin area for steam coal, house coal over it had been worked.

Mr. W. D. Woolley.

Mr. D. F. Davies, F.G.S. (Cross Hands), said the paper indicated that the diffusion of gas was slow, otherwise none of the men would have escaped at the bottom part of the slant. As to types of lamps, he should not like to manage a colliery at which none but electric lamps were used. He did not say, however, that they should all be oil safety lamps. He had prepared some notes on Mr. Roblings' paper in the train, but he would furnish them to the Secretary for inclusion in the 'Proceedings' as time was short.

Mr. D. F. Davies, F.G.S.

Mr. D. F. Davies, F.G.S., writes:

The section of the Lower Pumpquart seam at Ponthenry differs from that of the same seam of the Mynydd Mawr and Ammanford district inasmuch as the top coal 6 ins. in thickness is absent in the latter districts and the seam is in one coal about 2 ft. 8 ins. in thickness, with a hard clod about 8 ins. in thickness coming down on top of coal.

This seam has a feature differing from any of the other seams of our district of often nipping out as in this case at Ponthenry, and it is not rare for the seam which is 11 yds. above —namely the Lower Triquart—to be running quite regular, whereas the Lower Pumpquart will be nipped out, top running quite regular for a distance, in one instance I know of, of 200 yds., and you often see rashings and small coal mixed taking the place of the seam itself.

I know of several large blowers breaking out in this seam, but not a single instance of anything like the magnitude of this one at Ponthenry Colliery, neither have I known of a

Mr. D. F. Davies, F.G.S.

single case in this seam, the same attended with an outburst of small coal.

I entirely agree with the writer that the slight fall of the barometer was only a coincidence, as the pressure of the gas must have been so great that the slight depression of atmospheric pressure would have had an infinitesimal effect.

I also agree with the writer that the gas given off must have been occluded in the coal, but the particles of this coal were very friable, and possibly of a porous nature, therefore to my mind it was not a question of whether the gas was occluded in this friable coal at a greater pressure than in the more compact portions of this seam, but to the physical inability of coal of this nature to retain its occluded gases when the pressure in front of same had been released, and I think this is proved by the interesting and instructive analysis of Mr. Seyler, which shows this coal had only been able to retain some 18 per cent. of its CH_4.

Mr. Roblings raises a very interesting point to the geologist as to the reason of the crumbling nature of the seam at this point, as to whether this is due to crushing or to the intense pressure of the occluded gases. Might I suggest to him another? Professor Fearnsides, in his investigations of nip-outs or wash-outs in Yorkshire, has propounded a new theory that this is due not to ancient river beds, but to horizontal faults, and if so, that this movement had taken place before the deposition of the 6 ins. of top coal.

Mr. Dyer Lewis has raised a very important point in the discussion as to whether the 148 men would have been warned in sufficient time to come to safety had only electric safety lamps been in use. In a colliery in our district, working the same seam—namely, the Lower Pumpquart—a blower of gas broke down in the level heading on the morning shift, and at this colliery only electric safety lamps were in use ; the workmen

ı the topholes were only rescued at considerable difficulty, ıd I believe some of them were overcome and unconscious ·hen rescued, and artificial respiration had to be resorted to) revive them. It is difficult to say what would have happened ad it been such an outburst as the one at Ponthenry. Mr. D. F. Davis, F.G.S.

I am personally of opinion that there should be one oil ıfety lamp in each working place, and if two men are working ı the same working place the other lamp might be an electric ımp.

I congratulate Mr. Roblings on giving us such a clear escription of this rare occurrence in his excellent paper.

The discussion was adjourned.

Other papers adjourned were those of Mr. A. E. Parker on he Cement Gun and Mr Ernest Breffit on the Imperial Tie 'amper.

CAUSES OF SUBSIDENCES AND THE BEST SAFE-GUARDS FOR THEIR PREVENTION.

By R. C. Morgan.

(Awarded First Lewis Prize 1920.)

CAUSES OF SUBSIDENCES AND THE BEST SAFE-GUARDS FOR THEIR PREVENTION.

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This subject is one about which very little is really known, and is one which will require a tremendous amount of study of the results of observations and experiments, in every country where mining is extensively carried on, before it will be possible to formulate any theory or theories to guide mining engineers as to the best means of overcoming the dangers resulting from subsidences.

For the sake of clearness, the writer purposes using the terms adopted by Mr. H. W. G. Halbaum in his paper 'The Great Planes of Strain in the Absolute Roof of Mines,'[1] and illustrated in Fig. 1, as follows:—

'Mined Strata'—the subcylindrical column of strata, the perimeter of which is the excavation proper.

'Dead Zone'—the portion of mined strata which has settled through the maximum subsidence; behind HE, Fig. 1.

'Motive Zone'—the portion of mined strata still in process of sinking; HEJF, Fig. 1.

'Littoral Zone'—the disturbed strata immediately in advance of the 'mined strata'; JFBD, Fig. 1.

[1] *Trans. Inst. Min. Eng.*, 1906, Vol. xxx, p. 176.

'Prime Strata'—the strata immediately in advance of the 'littoral zone'; DBCK, Fig. 1.

'Absolute Roof'—the entire body of overlying strata.

'Nether Roof'—the short depth of roof immediately above the workings that timber might be expected to support.

'Vertical Face'—the vertical plane of the line of working face in longwall, or the goaf-line in bord and pillar workings; JF, Fig. 1.

'Prime Face'—the conterminous face of the littoral zone and prime strata, FD, Fig. 1.

'Stress'—the intensity of the force.

'Strain'—any alteration of figure produced by the application of force.

'Draw'—the horizontal measurement of the littoral zone (at the surface); JD, Fig. 1.

'Subsidence'—the vertical measurement of the displacement of the 'motive zone'; LH, Fig. 1.

'Angle of pull'—the angle between the vertical and prime faces; JFD, Fig. 1.

At the outset, it is evident that no subsidence can take place until after excavation has commenced. When a seam is being excavated two potential forces are liberated. One of these forces, due to gravity, is acting vertically downwards at a pressure which depends upon the specific gravity of the absolute roof, but which may be taken at one pound per square inch per foot in depth for the coal measures; and the other, due to the compressive strain produced by cooling of the earth's crust, acting in a horizontal direction, and projected against the former in a direction opposite to the advance of the working face. The reaction of these two forces accounts for the fact that the area of subsidence at the surface is always greater than that of the excavated area underground: in other words

it accounts for the 'draw.' It has been observed that the greater the draw the less the subsidence and the less the damage inflicted at the surface by mining operations.

The angle of pull has been found to vary from 7° to 34½° from the vertical, under varying conditions by different observers. This variation may be due to a large number of factors, and will be dealt with at a later stage.

That the second of the two forces is potential in the strata is proved by observation of what takes place when a cutting

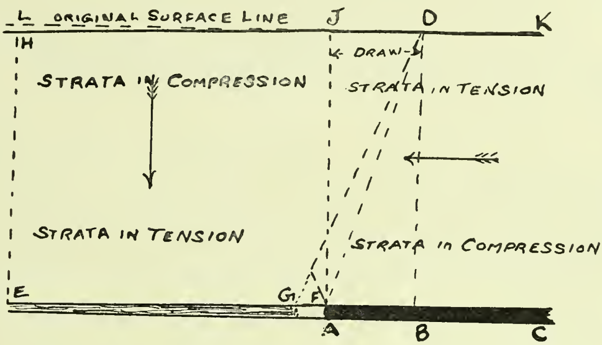


Fig. 1.

is made at the surface. The sides which are vertical at first move slightly towards one another, the movement being greater in soft strata than in hard.

What happens when the extraction of a seam is commenced will be seen from the following observations, which have been carried out by the writer in a new colliery.

The seam worked has a section of about 2 ft. 4 ins., and lies at a depth of 100 yards at the shaft, the full dip being 1 in 12.

This seam is overlaid with a bed of fairly strong clift, 2 ft. 6 in. in thickness which is ripped on the roadways, and above this is a strong clift roof about 27 ft. thick, and above that rock which is heavily watered.

A machine-cut face was developed and, until the headings

were in 60 yards and the stalls 30 yards, the entire workings were dry. It was observed that the bed of clift above the gobs had subsided slightly, so that a gap of $\frac{1}{4}$ inch was to be seen above it. The gobs were tightly packed in anticipation of the 'first squeeze.' Without any warning this squeeze came on accompanied by heavy 'pounces,' which lasted three days. These 'pounces' sounded to be in the roof just ahead of the face and back over the shaft pillar. Water appeared almost at once and gradually increased in quantity. The gobs were compressed 25 per cent., and the roof could be seen to have bent down at the edge of the shaft pillar. Several deductions can be made from these observations.

(*a*) It proves that the entire weight of the absolute roof does not act to compress the gobs, but that the strata acts as a beam which bends as the stress due to the potential forces becomes large enough. This beam is supported at either end on the coal face and shaft pillar respectively, and the gob underneath acts as a partial support.

(*b*) The heavy 'pounces' were produced by the change of strain in the rock particles. Fig. 1 illustrates this clearly. As long as the absolute roof was unfractured the nether roof was in tension, but as soon as a fracture occurred the various zones were formed. The nether roof in the motive zone would remain in tension, but in the littoral zone would change to compression, as this portion of the absolute roof would become a cantilever.

That fracturing of the nether roof did occur is proved by the appearance of water.

(*c*) If the gobs could have been so tightly packed as to be as strong as the coal which had been extracted, no subsidence could have taken place.

It is well known that the intensity of the squeeze which compresses the gobs and produces subsidence varies considerably and cannot be said to be due to any one cause. It will be seen that where we have two forces acting at right angles to one another and of varying intensity, the resultant will lie somewhere between the vertical and the horizontal, according to which force is the greater. The slope of the prime face will represent this resultant, and consequently the angle of pull will vary according to the relative strengths of the two potential forces in the absolute roof.

From this it will be seen that the greater the angle of pull the less the subsidence, owing to the potential force acting vertically downwards being less.

It becomes evident that a successful investigation of the causes of the variations of the angle of pull would yield results of the greatest importance, which would enable mining engineers to guard against subsidence damaging property.

The writer has carried out research work which has some bearing on this matter, and which aimed at trying to discover the reasons for the varying intensity of squeezes on different areas of workings in the same seam under practically identical underground conditions.

The seam selected for these investigations was the 9 ft. seam, which lies at a depth of 480 yds. at the shafts, and dips in a southerly direction at a gradient of 1 in 12 approximately. This seam was chosen because it was worked over wide areas and the packing material for the gobs was of a uniform kind.

Some means of measuring the intensity of the squeeze was sought after, and the writer tried the following method.

The method of working being longwall, the thickness of the seam worked ‘ through the face ’ was measured in two or three main roadways in each of four ‘ districts.’ The height

District No. 1.

Date.	Distance from face.			Height of pack in feet.	
	Feet.	Days.		A	
July, 30 1918	0	0		5·75	
	10	16·7		4·66	
	20	33·4		4·00	
	30	50·1		3·25	
	40	66·7		3·00	
	50	83·4		3·00	
	60	100·2		3·00	
	70	116·8		3·00	
	Feet.	Days. A′	Days. B′	A′	B′
Aug. 26, 1919	0	0	0	5·46	6·33
	10	15·2	15·6	4·87	5·66
	20	30·4	31·2	3·54	5·16
	30	45·6	46·8	3·50	4·58
	40	—	62·4	—	4·50
	50	—	78·0	—	4·50
	62	94·2	—	2·92	—
	81	123·2	—	2·83	—
			A	A′	B′
Levels . .			975′	994′	970′
Rate of advance			73 yds.	80 yds.	78 yds.

District No. 2.

Date.	Distance from face.			Height of pack in feet.	
	Feet.	Days C	Days. D	C	D
Aug. 19, 1918	0	0	0	5·92	6·58
	10	24·3	23·0	5·0	6·25
	20	48·7	46·0	4·33	5·0
	26	—	58·8	—	4·33
	30	73·1	—	3·83	
	40	—	92·0	—	3·75
	50	121·8	—	3·5	—
	60	146·2	138·0	3·5	3·75
	90	219·1	207·0	3·5	3·75
		C′	D′	C′	D′
Sept. 2, 1919	0	0	0	6·46	6·21
	10	24·3	27·03	—	5·50
	20	48·7	54·06	5·58	4·58
	30	73·1	—	5·42	—
	50	121·8	135·15	4·17	4·08
	60	146·2	162·18	4·08	4·0
	70	—	189·2		3·66
	80	194·8	—	3·83	—
		C	D	C′	D′
Levels . .		590′	580′	590′	580′
Rate of advance		50 yds.	50 yds.	53 yds.	45 yds.

District No. 3

	Feet.	Distance from face. Days. E	Days. F	Height of pack in feet. E	F
Date. Aug. 16, 1918	0	0	0	5·50	6·33
	10	25·4	10·9	4·42	5·5
	20	50·8	21·8	4·17	4·83
	30	76·2	32·7	3·58	4·5
	40	101·3	43·6	3·50	3·92
	50	126·7	54·5	3·50	3·66
	60	152·1	65·4	3·25	3·66
	86	218·0	93·5	3·25	3·66
		E′	F′	E′	F′
Date. Sept. 18, 1919	0	0	0	5·17	6·08
	10	22·1	—	4·25	—
	14	—	24·3	—	5·83
	20	44·2	34·8	3·50	5·17
	30	66·3	—	3·17	—
	40	88·4	—	2·83	—
	53	—	92·1	—	4·17
	60	132·7	—	2·50	—
	64	—	111·2	—	3·17
	70	—	121·8	—	2·67
		E′	F′	E	F
Level . .		1346′	1326′	1342′	1332′
Rate of advance		55	70	48	112

District No. 4

	Feet.	Distance from face. Days. G	Days. H	Days. J	Height of pack in feet. G	H	J
Date. Aug. 20, 1918	0	0	0	0	5·33	5·66	5·92
	10	20	12	14	4·44	4·66	5·75
	20	40	24	28	3·83	3·83	5·17
	30	60	36	42	3·5	3·58	4·25
	40	80	48	56	3·0	3·25	4·08
	50	100	60	70	3·0	3·0	3·66
	60	120	72	—	3·0	3·0	—
	93	—	—	132	—	—	3·33
	105	—	126	—	—	2·5	–
		G′	H′	J′	G′	H′	J′
Date. Sept. 18, 1919	0	0	0	0	5·67	6·17	5·92
	10	24·4	14·4	16·2	5·17	5·08	5·67
	20	48·7	28·9	32·4	4·83	4·50	5·33
	30	73·0	—	48·7	4·0	—	4·83
	40	—	57·8	64·9	—	3·58	4·67
	50	121·8	—	81·1	2·83	—	4·33
	60	158·3	86·6	97·3	2·63	3·17	4·17
	80	—	—	129·7	—	—	4·08
	90	—	—	145·9	—	—	3·75
		G	H	J	G′	H′	J′
Level . .		1215	1235	1230	1230	1255	1245
Rate of advance		61	101	85	50	82	75

of the pack was then measured at intervals back from the face until the measurements became constant, *i.e.* when the dead zone was reached. These results were tabulated, together with the rate of advance of the face per annum and the approximate level in feet below the ordnance datum.

The whole series of measurements were repeated after a year had elapsed, and another set of results obtained.

The results are shown on pages 54, 55.

A plan on a scale of 6 in. to the mile was next prepared, showing the surface contours and the points at which the measurements were taken underground, also the position of the faults in the 9 ft. seam (see Fig. 2).

Vertical sections showing the outline of the surface above the roadways were prepared so that the thickness of the absolute roof could be measured (see Figs. 3, 4, and 5).

It will be noticed that the distances from the face have been expressed as time in one column. This was done to eliminate the variations due to the rate of advance of face varying between 45 and 112 yards per annum in the different roadways. Sections showing the curve of the roof were plotted on this basis, and show that the rate of subsidence is generally much more rapid during the first period of twenty to forty days than at later periods, which is due to the gobs, as they become compressed, offering an increasing resistance to the forces producing subsidence (see Fig. 6).

The writer next considered a means of obtaining a comparison of the stress producing subsidence in the various cases. He decided to proceed as follows :—

As has been previously shown, the absolute roof may be regarded as a beam. In this case the portion of the beam undergoing stress would be that over the motive zone. The depth of this beam, being the thickness of the absolute roof, would be greater than one-sixth of the length, so that it becomes

evident that the shear stress is of more importance than the bending moment. To calculate this stress the maximum

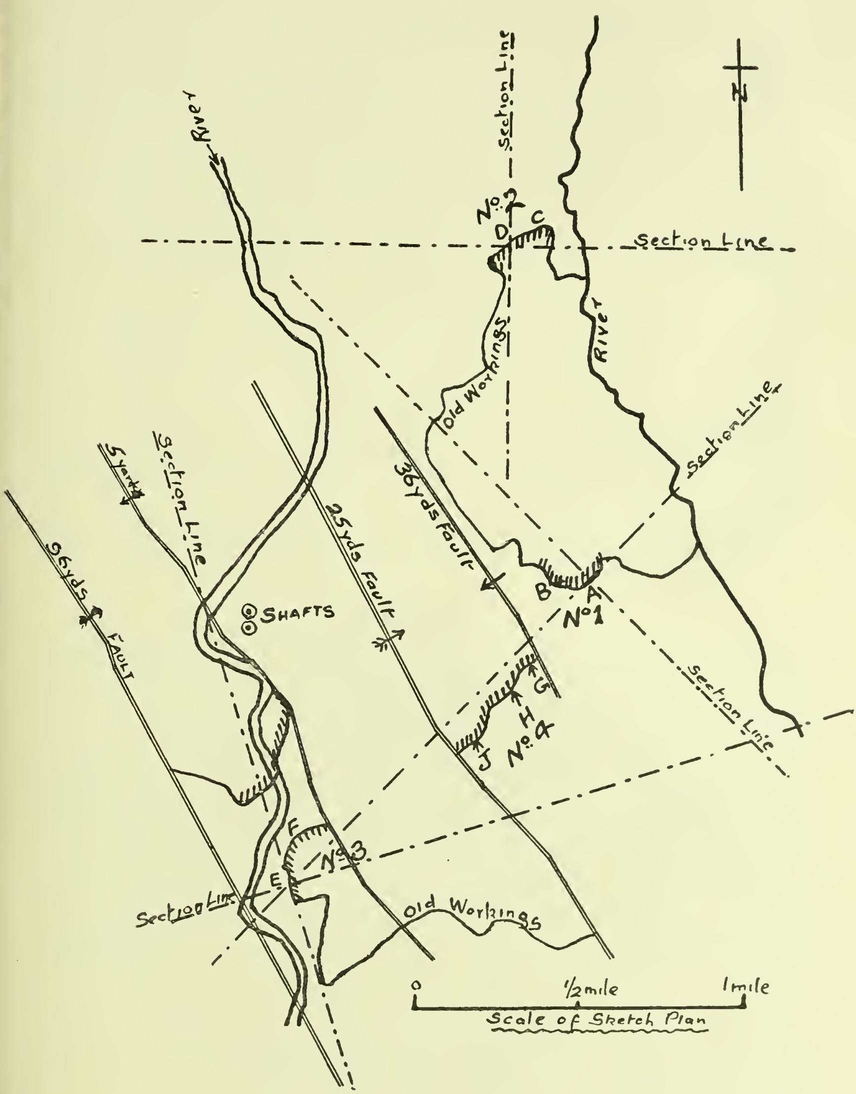
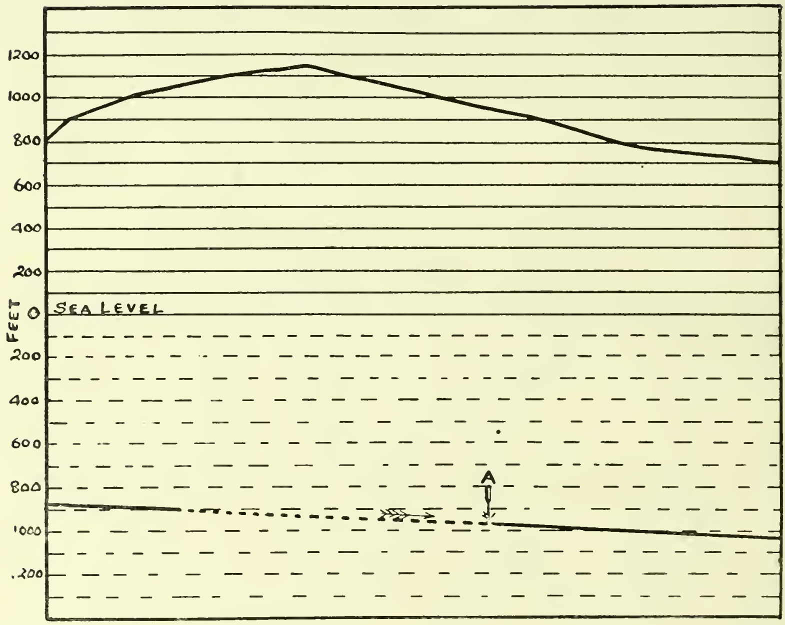


Fig. 2.

subsidence must be regarded as the deflection, and the width of the motive zone as the length of the beam. The ‘measure

District Nos. 1 & 4.

Longitudinal Section.



Cross Section.

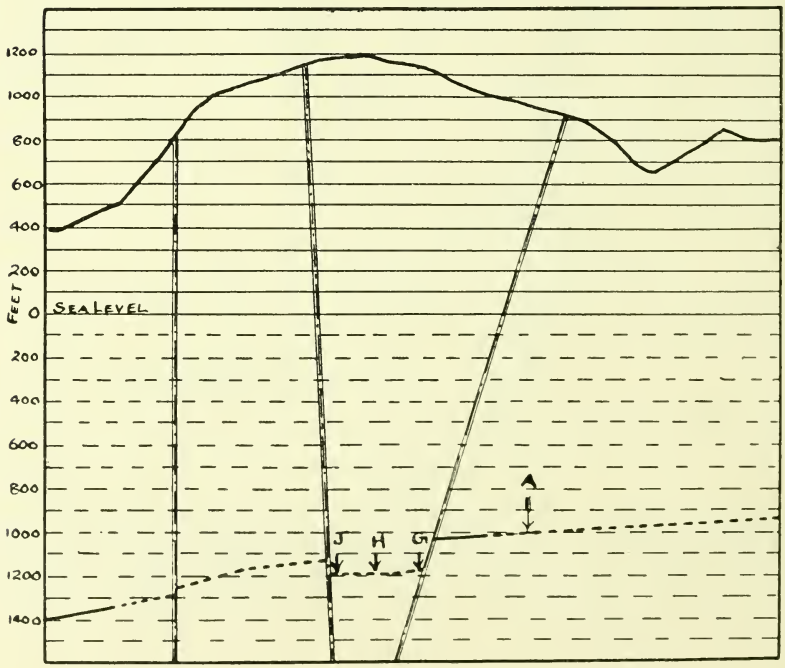
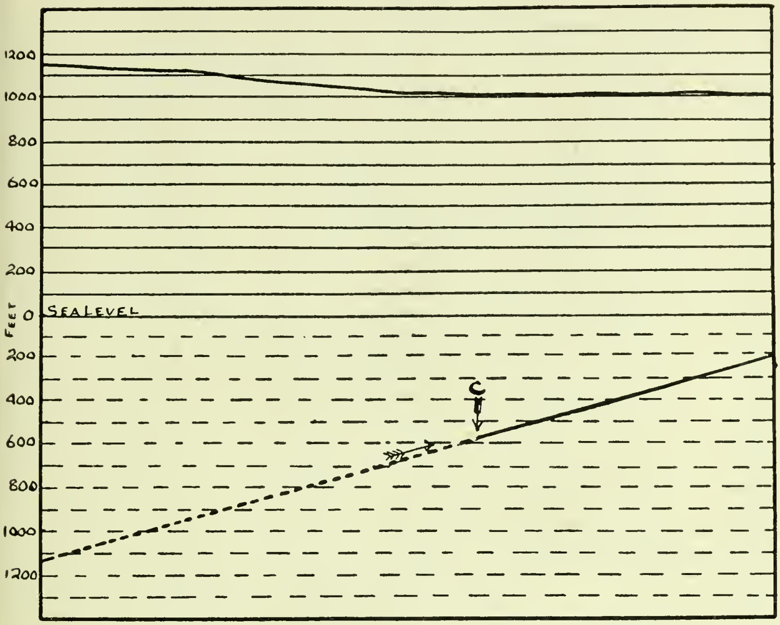


Fig. 3.

District No. 2.

Longitudinal Section.



Cross Section.

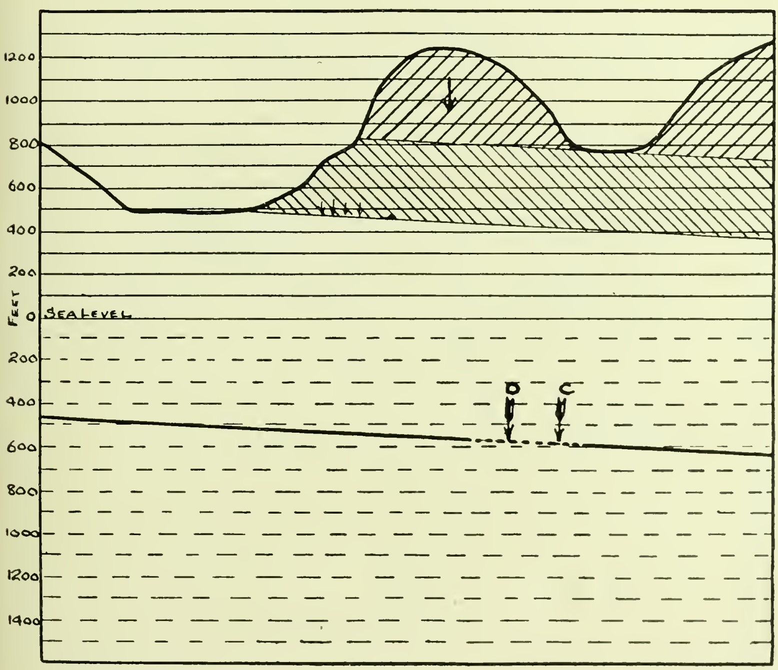
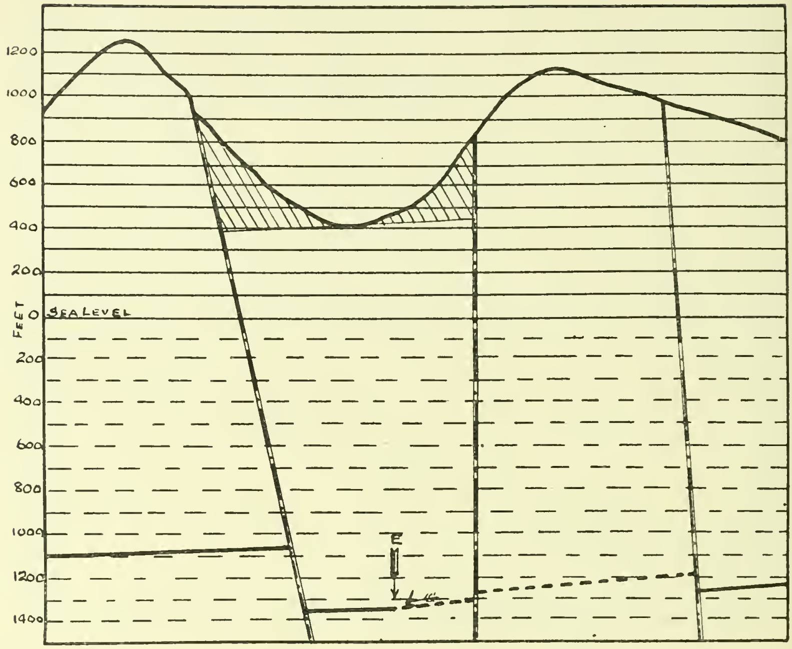


Fig. 4.

District No. 3.

Longitudinal Section



Cross Section.

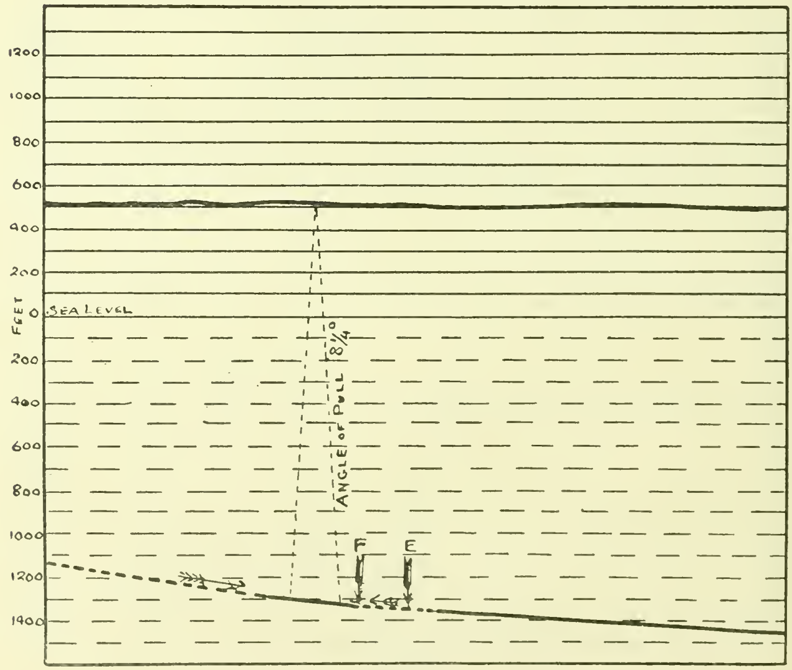


Fig. 5.

TIME BASE SECTIONS.

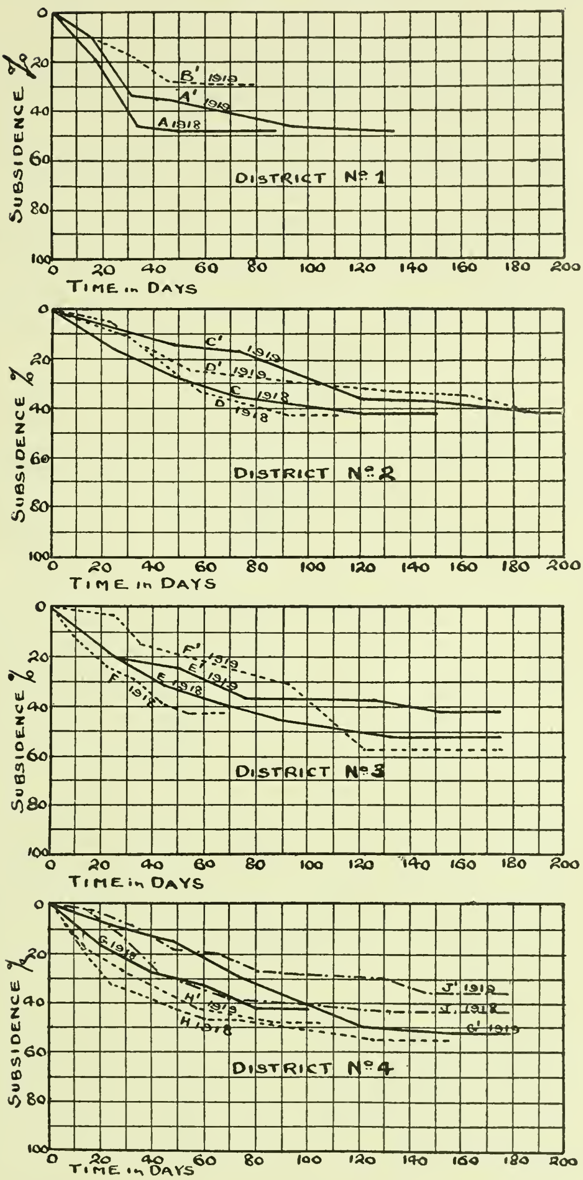


FIG. 6.

of the strain' is obtained by dividing the deflection by the length:

$$\frac{\text{maximum subsidence (in ft.)}}{\text{width of motive zone (in ft.)}} = \text{` measure of the strain.'}$$

This result multiplied by a constant would give the actual stress per unit area. In this case the constant is of necessity unknown, but would be the same for all the cases under consideration (*i.e.* the absolute roof is of the same structure throughout), so that the 'measure of the strain' may be taken as the 'relative stress.' The results are as follows:—

District and point of measurement.		Maximum subsidence.		Time taken in days.	Width of motive zone in feet.	Average rate of subsidence per day. %	Relative stress.	Rate of advance of face in feet per annum.	Thickness of absolute roof.
		%	Feet.						
District 1.	A	48	2·75	66·7	40	0·720	0·688	219	1920′
	A′	48	2·63	123·2	81	0·389	0·325	240	1920′
	B′	28	1·83	62·4	40	0·449	0·458	234	1920′
District 2.	C	42	2·42	121·8	50	0·345	0·484	150	1650′
	C′	42	2·63	194·8	80	0·218	0·329	150	1650′
	D	43	2·83	92·0	40	0·468	0·708	159	1650′
	D′	42	2·55	189·2	70	0·222	0·365	135	1650′
District 3.	E	42	2·25	152·1	60	0·276	0·375	144	2140′
	E′	52	2·67	132·7	60	0·392	0·445	165	214 ′
	F	43	2·67	54·5	50	0·789	0·535	336	2140′
	F′	57	3·41	121·8	70	0·468	0·487	210	2140′
District 4.	G	43	2·33	80·0	40	0·537	0·583	183	2410′
	G′	52	3·04	158·3	60	0·328	0·506	150	2410′
	H	56	3·16	126·0	105	0·445	0·301	303	2410′
	H′	48	3·00	86·6	60	0·555	0·500	246	2410′
	J	43	2·59	132·0	93	0·326	0·279	255	2410′
	J′	36	2·17	145·9	90	0·246	0·241	225	2410′

The following graphs were then plotted.

Relative Stress and Rate of Subsidence (see Fig. 7).—The

graph relating to each district was plotted separately and the results, with one exception, were straight lines passing through the origin. It is interesting to consider what shape these graphs could be expected to assume.

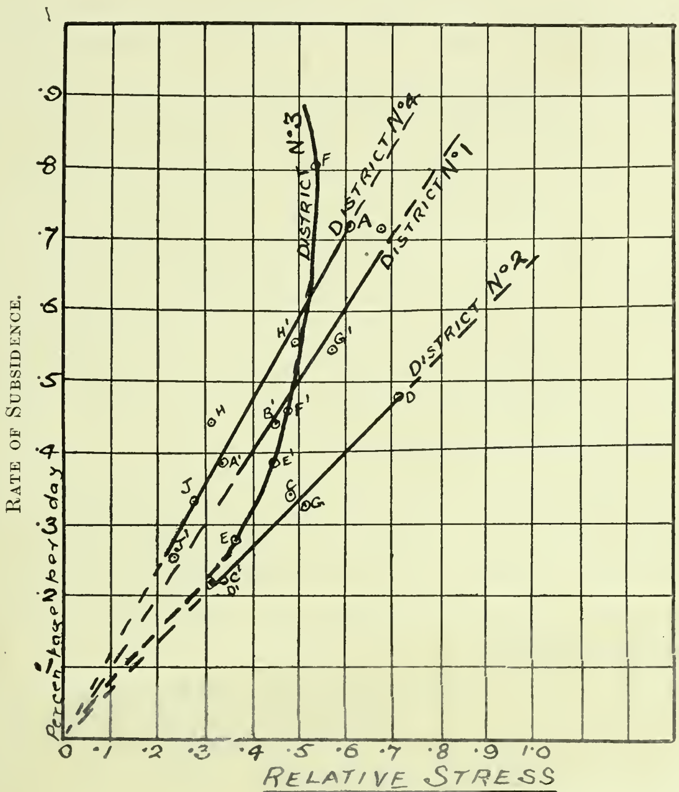


FIG. 7

When the relative stress is infinitely small, then it is to be expected that the rate of subsidence would be infinitely small, so that the graph would pass through the origin. On the other hand, if the relative stress is infinitely large, then the rate of subsidence should be infinitely large. The rate of subsidence, which is a measure of the distance moved through by the absolute roof in a given time, multiplied by the relative

stress, which gives the pressure per unit area, would give the relative power expended during subsidence.

It is interesting to consider each district separately.

District No. 2.—An examination of this graph shows that for a given rate of subsidence the relative stress is greatest, and consequently the power expended during subsidence, for the cases under review. It would be expected that this would be the case where the thickness of absolute roof was the greatest, but in this case the total thickness is the least. The writer would suggest that the reason is to be found by referring to Fig. 4, where it will be seen that the absolute roof consists of three parts: the portion from the valley downwards, which has the form of a beam supported at both ends (' balanced strata ') ; the portion above this, which has the form of a cantilever; and, finally the hill, which is a load not supported at either end (' unbalanced strata ').

It is evident that a beam loaded in this manner would be subject to very heavy stresses, even when the loads are ' dead.' But as soon as any movement takes place, the unbalanced strata would tend to become a live load and thus greatly increase the stresses.

District No. 1.—In this case the relative stress is not as great for the same rate of subsidence as in the preceding case. An examination of Fig. 3 reveals that a large fault overhangs this district whilst the thickness of the absolute roof is 1,920 ft. The presence of this fault, together with some effects from the subsidence taking place above District No. 4, would doubtless account for the power producing subsidence being greater than that in District No. 4, where the cover is greatest of all.

District No. 4.—This district, although it has the greatest thickness of absolute roof (2,410 ft.), shows the least relative stress for the same rate of subsidence. This is probably due to the fact that it is situated in a trough fault and that the

angle of pull is greater, due to the gravitational force being reacted upon by compressive forces in addition to the potential force (see Fig. 3).

District No. 3.—This graph is not a straight line, and has the appearance of the graph of the test of a material above the elastic limit.

The writer would suggest that the following is the reason. On referring to Figs. 2 and 5 it will be seen that roadway F was approaching another district which was being worked towards it. The first set of measurements were taken when the two districts were 320 yards apart, and the second set a year later, when they had approached to within 176 yards. The maximum subsidence in the first case was 43 per cent., and in the second case 57 per cent. In the first case this subsidence took place in 54·5 days, and in the second case in 121·8 days. On reference to Fig. 6 it will be seen that there was a very sudden compression, extending over the last thirty days, during which 27 per cent. of subsidence took place, or a rate of subsidence of 0·90 per cent. per day. A simple trigonometrical calculation shows that if the angle of pull is 8°–15′, then the 'prime faces' of each district have met at the surface, so that there is now no prime strata ahead of the No. 3 District and the beam is thus broken.

The writer plotted two other graphs: relative stress and rate of advance of face, also rate of subsidence and rate of advance of face (see Figs. 8 and 9).

In the first case the graphs were of an exceedingly complex nature. According to first principles they should be hyperbolas, and, in the case of Districts 1, 2, and 4, were of that order; but No. 3 District shows itself to differ from the others, probably for the reasons given above.

The second graph showed practically the same state of affairs.

The writer will now proceed to enumerate the various factors which will affect the angle of pull and consequently the subsidence, some of which have been proved by the results previously given.

1. *The nature of the packing material* used in longwall and the size of pillars, etc., left in other methods of working.

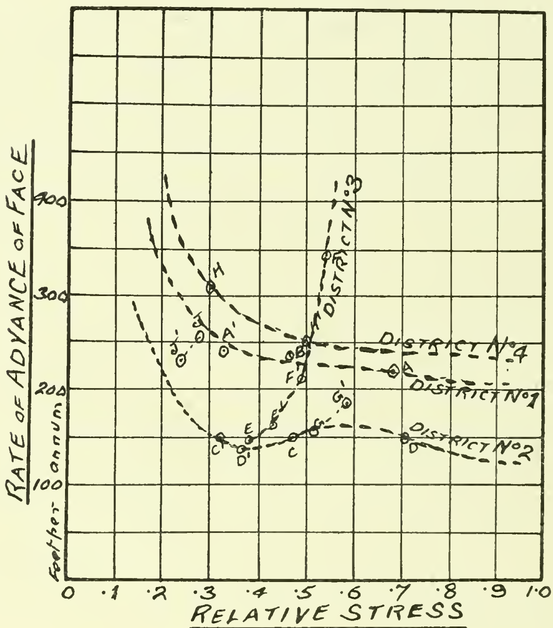
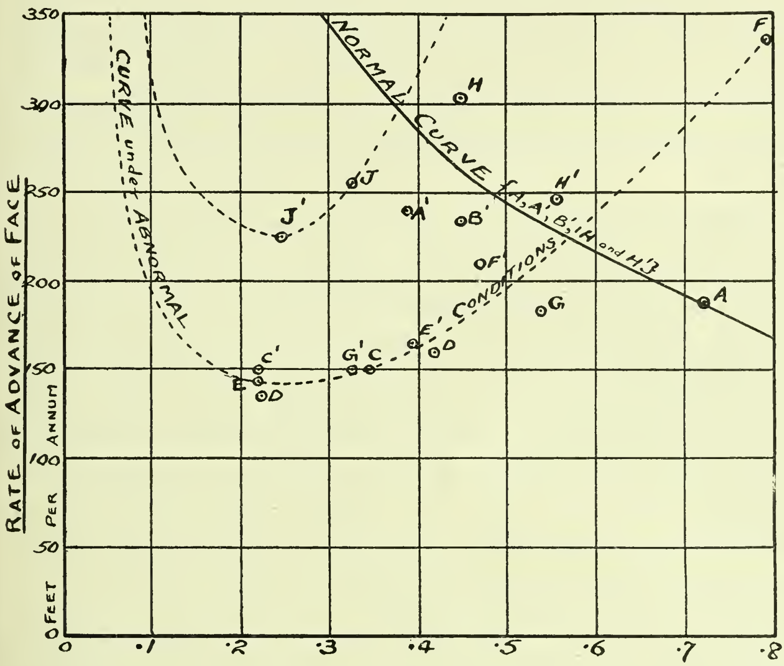


Fig. 8.

It has been shown that there is a force acting downwards producing subsidence, also that the packing material, etc., tends to neutralise this force. Therefore, the more nearly the strength of this support approaches that of the original seam the less the amount of gravitational force left to react against the compressive force. Hence the resultant of these two forces more nearly approaches the horizontal, and the angle of pull becomes greater, and *vice versâ*.

2. *The thickness of the seam worked* affects the angle of pull

for several reasons; the most important being that the method of working adopted is usually very irregular in very thick seams, which causes the absolute roof to break off with almost vertical prime faces, so that consequently the angle of pull is much less and the subsidence greater. The packing of



RATE OF SUBSIDENCE.

FIG. 9.

thick seam workings is usually very inefficient, and the rate of advance of the face necessarily slower than in thinner seams.

3. *Depth of seam from surface.*—It is known from experience that with shallow workings the surface is affected very considerably by sudden subsidences, and the area so affected is very little larger than that of the excavated area underground. This is probably due to the fact that invariably the strata is very much jointed with 'clay joints,' and thus would not

behave as a beam, but would be more inclined to slide down in sections. Thus the gravitation stress would be very much greater than the compressive stress, and the angle of pull consequently small.

It has been suggested by Prof. Knox that the angle of pull is likely to increase with depth, owing to the draw of the littoral zone against the motive zone assisting to support the absolute roof and allowing it to sink gradually in slightly curved form without fracture. This suggestion seems to be proved by the results obtained and graphed as previously stated (see District No. 4).

There has been much speculation in South Wales as to the reasons for the excessive squeeze met with in the lower seams, and it has been suggested that this was due to bad roof and the depth at which the seams lie. The question of depth cannot be said to be the deciding factor, for many collieries in other coalfields are much deeper than the average Welsh colliery and this squeeze is not met with. It has also been suggested that the hills and valleys under which the coal is mined are responsible to a large extent for this excessive squeeze, and the writer is inclined to favour this view. It has been shown that the absolute roof undoubtedly behaves as a beam, and, if this beam is taken to represent the balanced strata, then the unbalanced strata may be regarded as loads on it. These unbalanced strata or the hills are invariably steep in contour and, as the motive zone passes under them, tend to move very easily, bringing heavy loads on the balanced strata and in turn on the workings underneath, as previously shown in the case of District No. 2.

4. *The direction of working* would greatly influence the subsidence in cases where the absolute roof was badly jointed, because, if the prime face is parallel to the jointing, the roof would break and not bend.

5. *The rate of advance of the face* is known from practical experience to influence the squeeze, the roof tending to bend rather than break with a rapid advance, due to the force in the motive zone not having time to break through.

6. *The nature of the absolute roof* is bound to affect the subsidence and the angle of pull in much the same way as the nature of the material in any beam would affect its behaviour under load.

Where the strata are soft the angle of pull is small, due to the lack of cohesion among the rock particles and the consequent liability to fracture.

7. *Presence of Faults.*—It has been shown previously that the presence of faults in the absolute roof affects the ratios between the rate of subsidence and the relative stress, the rate of subsidence being higher where a fault overhung a district (Fig. 3). This is due to the prime face being intercepted and deflected by the fault making the angle of pull less. In another case a trough fault partially arrested subsidence, with a consequently increased angle of pull.

8. *The dip of the strata* plays a very important part in determining the relation between draw and subsidence. In horizontal strata the gravitational force must be at its maximum so that the draw would be a minimum, but the opposite is obviously the case in a vertical seam, where all movement of strata tending to close the space, from which the coal has been extracted, would be in a horizontal direction and would consequently be 'draw.' What the angle of pull is likely to be, at dips varying from the horizontal to the vertical, is largely unknown, and is a subject which requires a good deal of research work to be done.

9. *The contour of the surface* has been shown to affect the subsidence, and it is a well-known fact that damage at the surface is greater on steep slopes than on the flat, doubtless

due to the sudden movements of the hills, and the greater horizontal displacements for a given vertical subsidence than is the case with a flat surface.

10. *The general geological structure of the absolute roof* will obviously affect the amount of potential compressive stress, and consequently the angle of pull. In the case of anticlinal and synclinal folds, this stress would be less in the former case than in the latter. There would also be greater liability to fracture in the former case.

Up to this point the writer has discussed the causes of subsidences, together with the various factors which influence or may influence their intensity, and has given an account of the results obtained from a certain amount of research work which he has carried out. Whilst these results are far from being of a conclusive nature, still there seems to be 'something in them,' and he would suggest that a large amount of work carried out, on similar lines, over widely distributed areas, would be likely to yield substantial results, which may in time be sufficient to formulate the laws governing subsidence.

Having discussed the causes, the next question is how best to safeguard against subsidences and the attendant evils.

The primary cause of subsidence cannot be remedied, since the extraction of coal, etc., must of necessity be proceeded with.

The next best thing to do is to try to replace this coal, etc., with a material of the same strength.

This problem has been troubling mining engineers from the commencement. The problem becomes increasingly difficult the thicker the seam worked, owing to lack of sufficient stowing material, and to the impossibility of building this material up to the roof.

The rate of extraction of the seam in even thin seams

has a distinct bearing on this question, provided the seam does not provide its own packing material.

Where a thin seam is worked by machine-cut conveyer faces, and is of a perfectly clean section with good roof, this problem becomes incapable of solution, as is well known, because the extraction of the seam is proceeded with much more rapidly than rubbish can be stowed away in the gobs, and, as the tendency in the future will be more and more in the direction of what has been called 'intensive mining,' this problem of stowing must require increasing attention.

The nature of the packing material available must of necessity affect the strength of the support afforded to the roof.

Research work in Germany has established the following facts with regard to subsidence in German mines.

When the packs were made with small grained pit rubbish, the subsidence was 25 per cent.; when made with sand, about 8 per cent.; and when hydraulically stowed with sand, complete immunity from subsidence was obtained.

In several cases where various materials were used (sand, clay, ashes, etc.) for hydraulic stowing the subsidence varied between 0·03 per cent. and 7·8 per cent.

Subsidences in this country are often 50 per cent. and over with hand packing, which shows that the packing is very inefficient. It is evident, therefore, that the best method of preventing subsidence is to use hydraulic stowing. As the question of its application to existing mines is largely an impossibility, owing to the general lay-out requiring to be altered, so that all stowing is done to the dip whilst the face advances to the rise, apart from the enormous capital outlay required for the costly pipe-ranges, it becomes necessary to consider what other safeguards can be used. The next best safeguard would be developing the workings in such a manner

as to avoid irregularly advancing face-lines, avoidance of leaving pillars which break the absolute roof, and keeping the face-line advancing at the fastest rate possible consistent with efficient hand-packing.

In cases where a seam is being worked underneath a surface which consists of hills and valleys, it would doubtless be beneficial to work the seam in such a manner that the face moved in a direction parallel to the valleys, as there would be less displacement of the slopes than when working in the other direction. This matter might well be made the subject of exhaustive researches, which would be preferably carried out in an area free from faults and contorted strata, and with moderate dips. The area available to the writer was unfortunately much cut up by large faults, so that the results obtained were not of a conclusive nature.

In conclusion, the whole problem may be summed up in a few lines.

The prevention of subsidence by replacing the seam extracted by a method of stowing which will make the packs as strong as the original seam is the best safeguard. Failing this, keep the faces regular and advancing as rapidly as possible in the direction which will prevent the absolute roof from breaking, and so distribute the movement over the largest possible areas.

POWDERED FUEL.

By Robert James, Wh.Sc., D.I.C., A.I.Mech.E.

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The successful use of powdered fuel has been known in connection with the manufacture of cement for many years, but it is comparatively recent that the extension of its use as a fuel for metallurgical and general purposes may be said to merit commercial consideration. The development in the use of powdered fuel which has taken place in America is largely due to an economic reason, namely, the failing supply of the natural gas fields in the Pennsylvania districts, together with the increasing price of oil fuel.

As a result of experimental work induced by these conditions a considerable degree of success has been attained in the firing of various types of furnaces with powdered fuel, and in a manner which gives to the coal the flexibility of oil or gas.

On first consideration it might appear a retrograde step to discuss the question of using coal in a manner which must destroy the by-products, which could be conserved by a method of carbonisation, yet it is possible that progress in the use of powdered fuel, particularly in the burning of low volatile fuel, might assist in the development of the carbonising system by providing a method of burning the coke. It would be of course necessary to control the process of carbonising to produce a coke with sufficient volatile matter left in it to promote combustion, say 5 to 7 per cent.

Papers [1] recently read before this Institution, foreshadowing developments in coking practice, suggest that this is quite practicable. A carbonising system with the resultant coke pulverised and burnt with the correct proportion of air will approach to an ideal utilisation of our fuel resources.

In the meanwhile the use of powdered fuel offers so many ways of effecting economies, particularly with regard to the utilisation of small coal, screenings, and coal of poor quality, that in the interests of immediate national economy its application cannot be neglected.

In discussing the use of powdered coal the advantages gained by using coal in this manner, both as regards heat, economy, and labour saving with better working conditions, should be balanced against the cost of producing and handling the very fine powder, and the difficulties which in certain operations have to be overcome in dealing with the ash. That an encouraging degree of success has been obtained is evident from the comprehensive 'Report on Pulverised Coal Systems in America,' by Mr. Leonard C. Harvey, published by the Department of Scientific and Industrial Research.

Several small plants are now in operation and under construction in this country, but as yet no British data as regards working costs is available, and it is rather with a view to opening a discussion as to the possible application of powdered fuel to local requirements that this paper is written.

Preparation of the Fuel.—Experience already gained with powdered fuel has shown that the following conditions are essential to its successful application:

(1) Before grinding the free and combined moisture should be expelled by artificial heat down to 1 per cent. or less.

[1] S. R. Illingworth, *Proceedings of the South Wales Institute*, Vol. 36.

(2) Coal should be powdered so that 95 per cent. of the powder will pass through a screen of 100 meshes to the inch, and over 85 per cent. through a screen of 200 mesh. To crush coal to this degree of fineness requires an expenditure of power equal to 17–20 kilowatt-hours per ton. In large plants the preparation and handling of the coal up to this point is carried out in a central building which is termed the Mill House.

The usual practice is briefly as follows :

The coal is delivered alongside the pulverising-house and dumped into a storage hopper. If large coal is being used it is then passed through a crusher to break the coal down to about $\frac{3}{4}$-inch mesh, so as to assist evaporation of the moisture in passing through the drier; the coal is then elevated to the top of the building and carried along a short belt conveyer. This belt conveyer passes over a magnetic pulley, Fig. 1, which removes pieces of iron, pick-heads, etc., from the coal, and so prevents damage to the pulveriser and the screens, which in certain types of plant are used for controlling the fineness of coal. The coal then passes by gravity into a storage bin from which it descends to the drier.

Driers.—Several types of drier are in use, usually hand-fired; one type, known as the Indirect Drier, is shown in Fig. 2. It will be noted that the hot gases from the furnace circulate around the outside of the drier shell which passes through the combustion chamber of the furnace. The hot gases are then caused to enter at the lower end of the drier and to come into direct contact with the coal in the rotating shell. Driers are usually designed to deal with coal containing 10 per cent. moisture to dry down to less than 1 per cent. It is essential that the temperature of the coal should be kept below 400° F.

in passing through the drier to avoid loss of volatile constituents. From the drier the coal is elevated again to the top of the building and fed into the dry coal-bins, from which it is passed to the pulverisers.

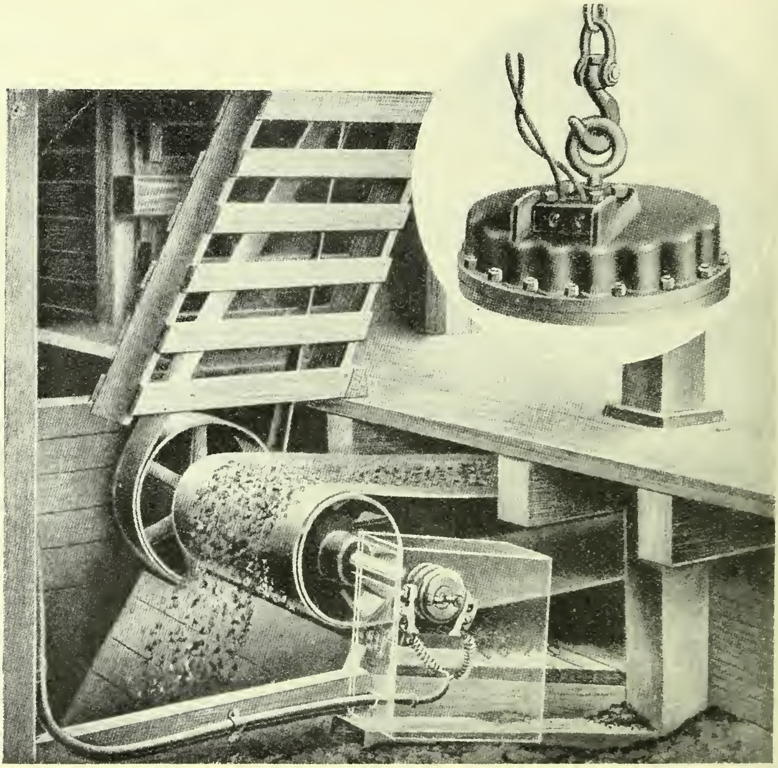


FIG. 1.—MAGNETIC SEPARATORS.

Driers are usually hand-fired, and the heat required to dry the coal to the given degree is about 55 B.Th.U. per lb. of fuel dried.

Pulverisers.—In general the pulverising machines use either air separation or screen separation, the relative advantages of each method about balancing. With the air separation method there is less possibility of dust escaping to the

atmosphere, but screen separation gives probably a greater percentage of extremely fine powder.

Machines for pulverising coal are similar in construction to the machines used in the preparation of stone dust. Mechanically there is much to be said for the heavy slow-running type of pulveriser as against machines of the beater type running at high speeds. It is usual to make the beater arms of special manganese steel to withstand the excessive wear and tear, otherwise the quality of the finished product will rapidly deteriorate.

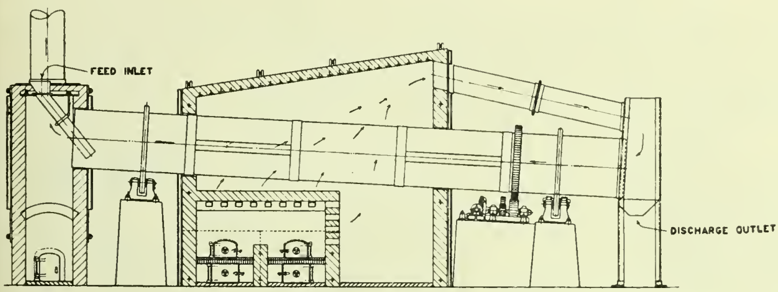


FIG. 2.

Distribution Systems.—There are three distinct methods of transporting the coal to the burners:

(1) By screw conveyers delivering into storage bunkers fitted at the furnaces.

(2) By suspension of the coal dust in low-pressure air, and sending it round an outward and return path, the fuel being tapped off by branch connections to individual units.

(3) By high-pressure air delivering the coal dust in known quantities into bins at the furnaces.

The first method of transportation by screw conveyers is at present most in use. It has many advantages if the unit to be served is only a short way from the pulverising station,

but for long distances it suffers by comparison with the newer systems of air transmission.

The second system, known as the Holbeck system, is illustrated in Fig. 3, which shows diagrammatically the application of the system to the firing of a Babcock boiler.

It will be seen that the coal from the drier is conveyed by a screw to a small coal-bin which feeds the pulveriser. The grade of fineness required is obtained by air separation,

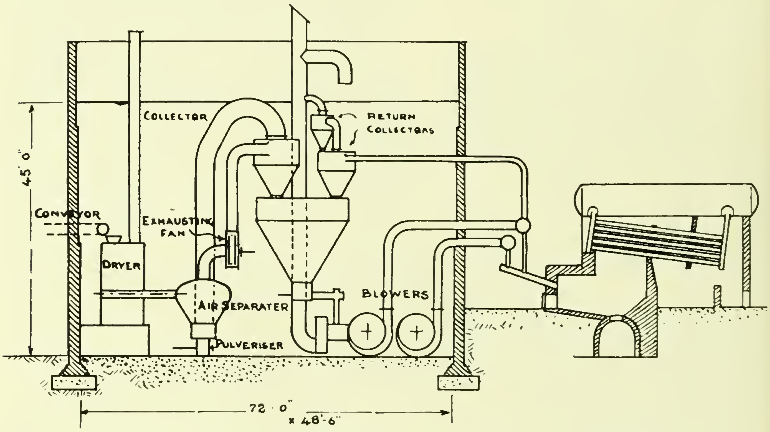


Fig. 3.—Holbeck System applied to Boiler Firing.

and the finished coal is taken through an exhauster to the main collector. The coal falls into the coal-bin, the air being returned to be used again in the pulverising mill.

Distribution.—From the powdered coal-bin the coal is taken by means of screw conveyers and delivered into the suction side of a distribution blower; this blower delivers the coal and the conveying air into the distributing pipe mains, the amount of powdered coal delivered to the mains being controlled by a variable speed motor governed by an automatic regulator; the ratio of coal and conveying or primary air being always kept constant, irrespective of the demands on the system.

The mixture of coal and air, about 1 lb. of coal to 60 c. ft. of air, is so rich that it is not inflammable, and before combustion can take place additional or secondary air must be added at the fuel burners. The scheme of distribution to various units is shown in Fig. 4.

The velocity of the air and coal through the main is about the order of 88 ft. per second, and therefore comparable to the velocity of steam through steam-pipes.

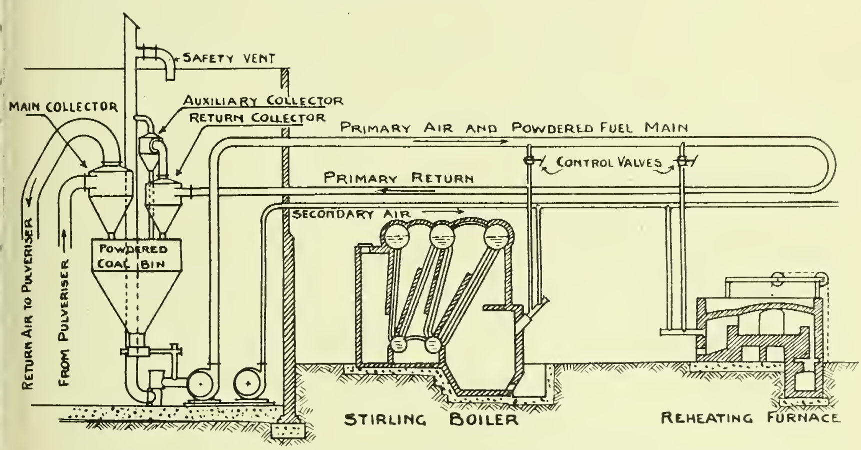


Fig. 4.—Diagram showing Holbeck System of Fuel Distribution.

A return pipe main is installed through which the fuel not required at the units being fired is conveyed to the return collector, the fuel not used being again delivered to the coal-bin, while the air which carries this fuel is drawn to the suction side of the distributing blower.

Some of the advantages of this system are :

(1) Elimination of storage bins at each individual furnace, thus saving space, also avoiding the possibility of the fuel caking in the bins.

(2) The coal dust in the system is all returned to the pulverised coal-bin within a few minutes after the furnaces are shut down.

Objections which might be raised against this system are:

(1) The possibility of a back-fire of the mixture through the piping system.

(2) With units situated some distance from the pulverising station the amount of piping required is considerable, and there appears to be a possibility of the velocity of the mixture falling to such an extent that a deposit of coal dust may be formed on the bottom of the pipe. To prevent any possibility of this it is necessary in long pipe lines to install booster fans along the supply line.

High-Pressure System.—This air transport system, known as the Quigley system, carries the pulverised fuel in bulk from the pulverising plant to the furnace bins. The fuel travels through ordinary 3-inch or 4-inch screwed piping. To provide for the possibility of a stoppage due to moisture in the coal, a small pipe carrying compressed air is arranged alongside so that tappings can be made into the coal-conveying pipe, and thus break up and clear any stoppage.

The diagram, Fig. 5, shows the general scheme of distribution. The fuel is fed by gravity from the bin at the pulverising plant into the blowing tanks, which are mounted on an automatic scale which indicates the amount of fuel available for transport. Air is admitted to the blowing tanks from a compressed air receiver, and the fuel flows through the pipes to bins located at each group of furnaces. Specially designed valves are fitted to tap from the main to each bin. These valves are usually controlled by hand, but an electrically controlled system is in operation by means of which the amount of fuel to be sent to each bin can be controlled from the central plant.

Control of Fuel to Burner.—From the furnace bin the fue

passes into the fuel feed regulator or controller. With the Quigley constant speed feeder the amount of fuel fed to the

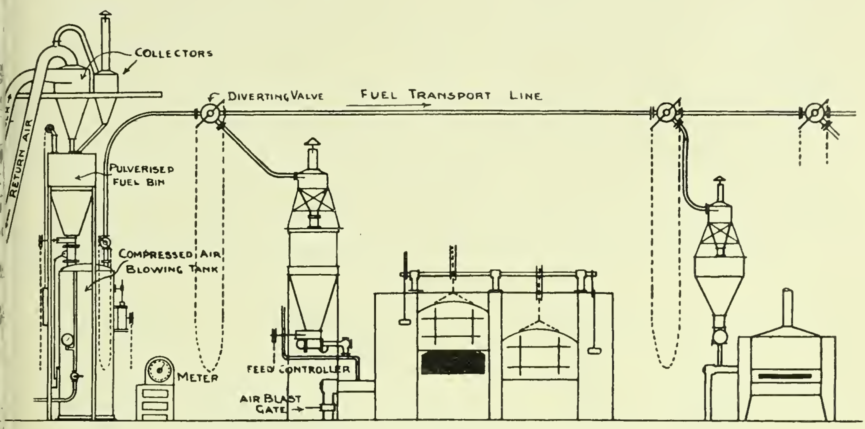


FIG. 5.—COMPRESSED AIR TRANSPORT SYSTEM.

burner is regulated by means of a hand wheel (see Fig. 6). The movement of this hand wheel controls the amount of fuel passing like the opening or closing of an ordinary valve.

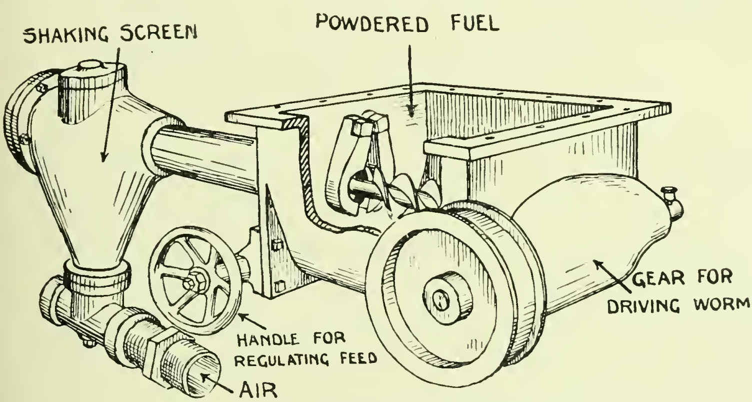


FIG. 6.—QUIGLEY CONSTANT SPEED FEEDER.

In the usual type of coal-dust feeder the worm is operated by a variable speed motor in order to control the quantity of fuel fed into the air-blast. The constant speed feeder makes it possible to run a number of feeders from line shafting. From

the discharge head of the controller the fuel is carried with about one-eighth of the air necessary for combustion into the burner (see Fig. 7). The secondary air is then introduced in just sufficient quantity at low pressure to effect correct combustion.

An obvious advantage of this system of transport is that the coal-dust pipe can be led under and over obstacles with just the same convenience as oil, water, or gas pipes.

It will be evident from an examination of the equipment

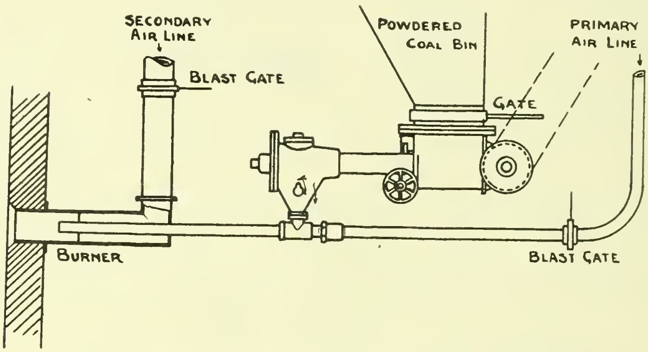


FIG. 7.—ARRANGEMENT OF CONTROLLER AND BURNER.

shown in the diagrams that in order to make a powdered coal plant a commercial proposition a substantial saving in fuel should be assured, although it must be borne in mind that firing with coal-dust carries with it many advantages which cannot readily be assessed at a monetary value. It may possibly be an advantage, before touching on the question of pulverising costs, to examine the conditions of the combustion of fuel in powdered form.

Combustion.—When fuel in ordinary form is burnt it is difficult to obtain the thorough mixing and proportioning of the air which is essential to the economy of any furnace.

In the best power station practice the quantity of air sent through the furnace approaches twice the amount

necessary for perfect combustion, while for the average plant working under conditions similar to colliery work the air passing through the furnaces may be three to four times the correct quantity, with consequent reduction of furnace temperature and efficiency. The diagram, Fig. 8, shows the lowering of the temperature of combustion of pure carbon due to various quantities of excess air.

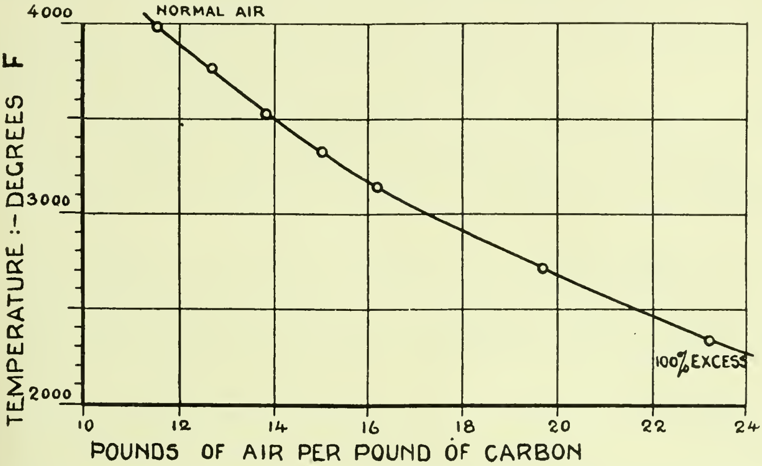


FIG. 8.—TEMPERATURE ATTAINED IN COMBUSTION OF CARBON WITH VARYING AMOUNTS OF AIR.

Mr. David Brownlie, in a paper before the Institution of Mechanical Engineers in March 1920, states that the flue gas analysis for 250 boiler plants, of which 76 per cent. were hand-fired and 24 per cent. mechanically fired, showed an average of 7·1 per cent. CO_2, with only four plants showing over 12 per cent. CO_2. With powdered fuel the mixing of the air and fuel is infinitely better, since the fuel is gently injected into the furnace in a very finely divided state, each particle surrounded by the necessary air. A simple calculation will suffice to show that a piece of coal 1 inch cube, if broken down to particles of about the order of $\frac{1}{200}$ inch cube, must expose a very much greater surface area to oxidation. As

these small particles enter the furnace the volatile gases are quickly driven off and consumed, and afterwards the remaining particles of carbon. Under these conditions the combustion is so good that a high temperature is rapidly acquired and easily maintained. The facility with which the combustion may be controlled under these conditions is evident when an examination of several boiler tests shows an average of over 14 per cent. CO_2 content in the flue gas.

Moisture in fuel, unburnt carbon in clinker, and ash are also causes of considerable loss with ordinary fuel which are almost entirely removed by the use of powdered coal.

Spontaneous Combustion and Explosions.—Objections often raised against the use of powdered coal are :

(1) Settling down and caking in the supply bunkers.
(2) Danger from spontaneous combustion in the bunkers.
(3) Danger from explosive mixtures of coal dust and air.

Undoubtedly quite a lot of trouble was caused in the early plants by the caking of the coal in the furnace bunkers. The caking occurred over the week end, or during periods when the furnace was not in operation, and necessitated clearing away the caked coal before putting the furnace in operation.

This trouble was due to insufficient drying of the coal, and is largely obviated by drying the coal down to 1 per cent. moisture before pulverising, and limiting the temperature at which the coal leaves the drier to about 200° F., the particular temperature depending on the nature of the coal. It is also an advantage to allow the coal to cool still further before entering the storage bin.

Danger from spontaneous combustion of coal in a closed bin is more imaginary than real, since, if overheating does occur and caking takes place, the air present in the voids is

insufficient to support combustion. It is now the practice only to store a twenty-four hours' supply of coal in powdered form, the reserve of coal being stored in lump form.

It is unfortunately true that several explosions have occurred with powdered coal plants. The danger of an explosion in the pulverising house exists when coal dust is allowed to escape into the atmosphere. This can be prevented, and in modern installations great attention is paid to keeping the plant clean, while the general trend of design is towards a dust-tight system.

An explosion can only occur when coal dust is mixed with air. Where the method of conveying the coal does not necessitate its suspension in air, the danger of an explosion is very remote.

Pulverising Costs.—The following is an estimate of the cost of pulverising 50 tons of coal per day. Owing to the very limited experience in this country the data is generally based on American figures.

	Cost per Ton. *s.*	*d.*
Labour Cost—		
Two men on three 8-hour shifts at 2*s.* 1*d.* per hour	2	0
Power cost on a basis of 20 K.W. hours per ton at $\frac{3}{4}$*d.* per unit	1	3
Drier Fuel—		
Assuming 40 lb. of drier fuel per ton with coal at 30*s.* a ton		6
Repairs—		
Per ton		6
Cost of plant, including erection, two grinding mills, one to act as standby, £12,000—interest at 6 per cent.	1	$2\frac{1}{2}$
Depreciation, 10 per cent.	2	$0\frac{1}{2}$
Total cost per ton . . .	7	6

With a plant dealing with 300 tons per day the cost per ton on a similar basis would of course be much smaller, working out at 5*s*. 3*d*. per ton. For plants requiring a smaller output than 20 tons per day, it would be out of the question to consider a complete drying and pulverising equipment

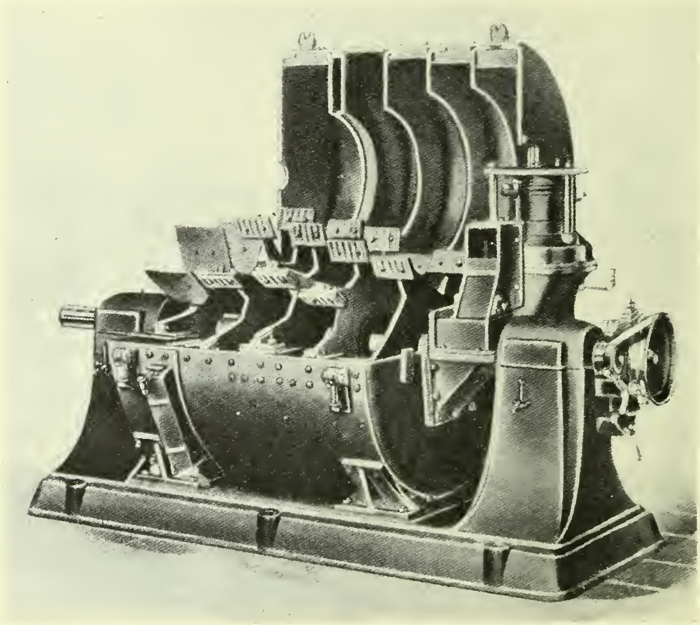


FIG. 9.—AERO OR TURBO PULVERISER.

unless additional extensions are contemplated, and in such cases a self-contained plant such as the 'Aero' or 'Turbo' pulverising machine might be adopted.

In this machine, which is of the beater type, the pulverising and air-mixing is performed in one operation. The machine, see Fig. 9, consists of a rotor on a horizontal axis revolving in a steel casing which is divided into several compartments; the one nearest to the delivery contains a blowing and exhaustive fan, the others contain paddles which crush and pulverise the coal by impact. Some air is allowed to enter

the pulveriser at the same end as the coal ; the amount of this air controls the velocity of the fuel through the pulveriser and thus regulates the fineness of the product. In connection with this type of pulveriser it is not usual to use a drier, and successful work has been done with coals containing up to 4 per cent moisture.

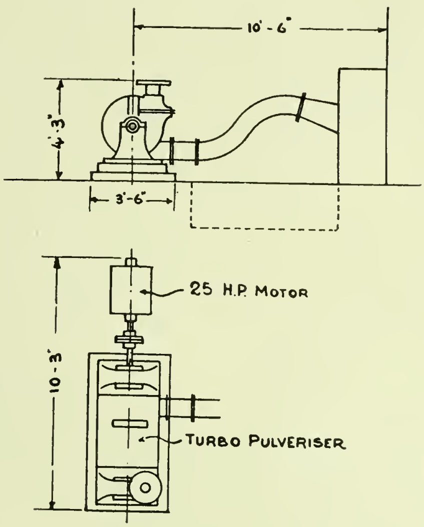


FIG. 10.—ARRANGEMENT OF PULVERISER AND BURNER FOR FIRING A SINGLE UNIT FURNACE OR BOILER.

Apart from particular applications where this unit is preferable it is a very convenient apparatus with which to carry out experimental work preliminary to the installation of a more elaborate pulverising system.

The general arrangement of a turbo-pulveriser firing a boiler is shown in Fig. 10. A turbo-pulveriser could very conveniently be fitted to fire boilers normally fired by gas, so that the boilers could be fired entirely with coal dust if the gas supply failed, or alternatively the pulveriser plant could be started to assist the gas-firing when insufficient gas is available to maintain the steam supply.

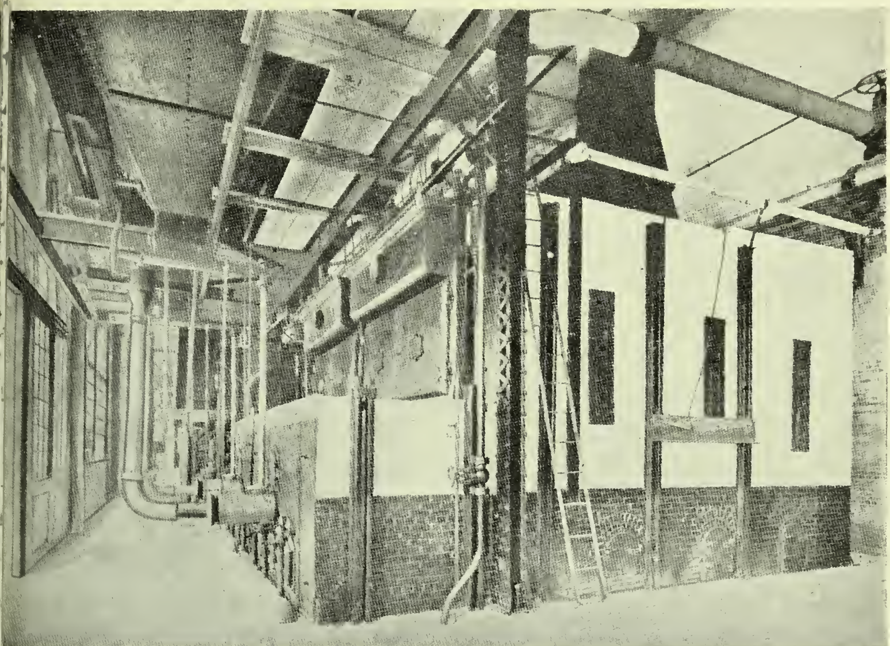
With pulverising costs at 7*s*. 6*d*. per ton it is necessary that the saving in fuel consumption should be of the order of 20 per cent., depending largely on the cost of the fuel. Thus in firing with coal at 42*s*. per ton a saving of 20 per cent. in efficiency would mean a saving of 8*s*. 4*d*. per ton of fuel fired. With pulverising costs at 7*s*. 6*d*. this would mean a considerable nett saving, in addition to the advantage of the elimination of the labour difficulties attendant on other methods of firing. It is, however, to the possibility of using coal of inferior quality that the writer would like to direct your attention, and the following remarks with reference to the use of dust-fuel for boiler plants may be of interest in this connection.

Boiler Plants.—The early troubles experienced in applying coal-dust firing to boiler plants were chiefly caused by erosion of brickwork and accumulations of dust. The recent improvement is due to finer grinding, with proportioning of the combustion chambers to suit the rate of firing, combined with low velocity of the fuel entering the furnace. The additional air required at the burner is supplied at just enough pressure to cause the mixture of coal and air to enter the furnace slowly. As a result the life of the brickwork is considerably increased, and the dust which reaches the boiler tubes is so slight that it can be cleared away by a small jet of steam applied at intervals.

Members are probably familiar with the English tests carried out in the Manchester district in 1905 with the Schwartz-Kopp method of firing by means of a rotating brush, and also with the degree of success obtained with the Bettington type boiler.

The first successful American boiler installation was that put down at the power station of the Kansas Railway Company. These boilers, a general view of which is shown in Fig. 11, have been in continuous operation since 1916, and following

their successful operation much larger plants are now under erection, the largest being that proposed in connection with the generating station of the Milwaukee Electric Railway Company, where an installation of eight boilers, each to operate



[Fi]g. 11.—View of O'Brien Type Water Tube Boilers Using Pulverised Coal in Power House of the M., K. & T. R. R. at Parsons, Kansas. In Continuous Operation since August, 1916.

at 250 per cent. above their normal rating, is to assist in supplying steam to a unit of 40,000 K.W. capacity.

The general practice in connection with power-house plants is to fire the boiler from storage bins at each unit, and Fig. 12 is an illustration of this system as adapted by the Fuller Engineering Co. to fire a Stirling boiler.

The provision of a large combustion space in front of or under the heating surface of the boiler is essential to any method of firing, as it ensures the extraction of about 65 per

cent. of the ash content of the fuel, either in clinker or semi-liquid form in this chamber. The fine dust is carried through the boiler, and it may in certain cases be necessary to provide for its deposition in the flues in such a position that it can be easily removed. A certain amount of the dust is carried up through the stack, but this is extremely fine and does not in any way appear to be a nuisance to the community.

At the present time several British firms are experimenting with the self-contained turbo-pulveriser. Also considerable interest is being taken in the plant designed to be fired by a separate pulveriser unit which is now approaching completion at the electricity works of the Hammersmith Corporation.

The writer recently had the opportunity of looking over this installation, which is to operate on the Holbeck system. The pulverising plant is designed to fire a Stirling boiler of 40,000 lb. evaporation, but if satisfactory it is contemplated to extend the plant to other Stirling and Babcock boilers.

The capacity of the pulveriser unit is 10,000 lb. of coal per hour. The coal, which is fed into the pulveriser-house by a conveyer, is passed through a drier before pulverising, so that the moisture content is reduced to about the order of 1 per cent.

The building required to house the plant for the preparation of the fuel occupies, as indicated in Fig. 3, a floor space of 72 ft. by 48 ft., with a height to the underside of the roof trusses of 45 ft. The whole plant, involving as it does a considerable amount of pipe work, is in striking contrast to the appearance of a stoker-fired installation. The system works under a slight vacuum, so that there should be no possibility of coal dust escaping into the atmosphere.

An interesting feature of the boiler end of the plant is the substitution of a regenerator for preheating the air to be supplied as secondary air to the burners, in place of the more

expensive economiser usually fitted for heating the feed-water. The burner is of simple construction, being of cast iron entering the brickwork at an angle and cut off flush with the brickwork on the inside of the furnace.

Range of Fuel.—The conditions of combustion of fuel fired in powdered form admit of a wide variation in volatile and ash content. It is now possible to burn bituminous or semi-bituminous coal even when the ash content approaches 40 per cent. The higher the melting-point of the ash the better the operating conditions, since ash with a high melting-point tends to deposit as a dust, whereas ash of low melting-point slags.

In a paper before the West of Scotland Iron and Steel Institute, Mr. J. S. Atkinson states the results of tests carried out in France on a boiler fired with a turbo-pulverising set, using coals of the following quality, with the special object of studying the behaviour of the ash :

		Per Cent.			Per Cent.
Coal (A)	Volatile matter	20·8	Coal (B)	Volatile matter	18·7
	Ash . .	15·6		Ash . .	45·5
	Moisture .	1·4		Moisture . .	6.0

With coal (A) the ash was sticky in character but easily removed from the bottom of the combustion chamber. The dust deposited on the tubes and at the back end of the boiler was dry and fine and easily removed. The deposit in the combustion chamber with coal (B) was naturally heavy, but was easily removed when at a high temperature and during the working of the boiler. The deposit on the tubes was dry and fine ; but it was necessary, in order to maintain the normal working of the boiler, to periodically blow this dust away with a steam jet. The high moisture content with this coal caused some trouble with the pulveriser. The following figures are interesting as being obtained in a recent

test on a French boiler with a coal containing 30 per cent. ash. Steam was generated at 120 lb. per square inch from a cold feed with the boiler evaporating 77 per cent. in excess of its normal rating.

Calorific Value of Coal. B.Th.U.	Percentage Ash.	Temperature in Combustion Chamber.	CO_2 Reading.	Evap. from and at 212° F.	Efficiency.
9000	30	2100	13·5	6·5	69·6

The general results obtained in American practice with coals of rather better quality than the above are shown by the statement below, which has been extracted from Mr. Harvey's Report (page 38), where the results of eleven tests carried out in 1916 on the boiler plant shown in Fig. 11 are tabulated.

Coal.	Proximate Analysis.			Calorific Value B.Th.U.	Flue-Gas Analysis.			Equivalent Evaporation from and at per Lb. fired.	Efficiency.	Per Cent. Rating.
	Vol.	Fixed Carbon.	Ash.		CO_2	O	CO			
Mineral slack	28·2	48·7	21·9	11,580	10·7	9·3	0	8·38	71·5	125
Semi-anthracite Kansas	22·9	59·9	17·7	12,628	15·8	3·5	0	8·66	69·6	137
Texas lignite	47·1	35·4	10·5	11,250	12·5	8·5	0	7·26	67·4	143

Efficiency.—The ease of control with dust-firing, approximating as it does to conditions of oil-firing, is so good that it is possible to maintain efficiencies of 75 per cent. or over for long periods of time.

This is an important point in its favour, as it is highly improbable that the average overall figure of even high-class stoker installations in a modern boiler-house is more than 63 to 65 per cent. efficiency day in and day out, although a carefully conducted test on a single boiler for twelve hours or so might show perhaps 80 per cent. efficiency.

The tabular statement following shows the results of comparative evaporative tests carried out in 1920 at the Chicago works of the Inland Steel Company before and after the conversion to powdered fuel firing.

Method of Firing.	Evaporation per Lb. of Coal Fired.	Percentage CO_2 in Flue Gas.	Boiler Efficiency per Cent.	Calorific Value of Coal. B.Th.U. per Lb.
Hand-fired .	7·66	9·6	63	12,300
Powdered fuel .	9·88	14·2	83	12,300

Flexibility.—A remarkable feature of dust-fired boilers is the ability to respond to fluctuation in steam demand ; the efficiency can be maintained steady for loads varying from 50 per cent. to 150 per cent. of normal rating. For normal steaming excellent results are obtained with mechanical stokers, but the efficiency falls off at overloads, and the time for which an overload can be carried is limited owing to clinker accumulation and overheating troubles. A further point is the elimination of banking losses. For boilers working under variable load conditions similar to colliery work, the fuel used for this purpose is considerable. With a range of boilers supplying steam to winding-engines about 50 per cent. of the annual coal consumption is used simply to keep the boilers under steam. Under a system of dust-firing it would merely be necessary to shut off the fuel and close the damper. The boiler pressure would fall at the rate of a few pounds in several

hours, and the boilers could be put on duty again a few minutes after starting the fuel feed.

It must be understood that the writer, in setting forth the above advantages of firing with powdered fuel, does not

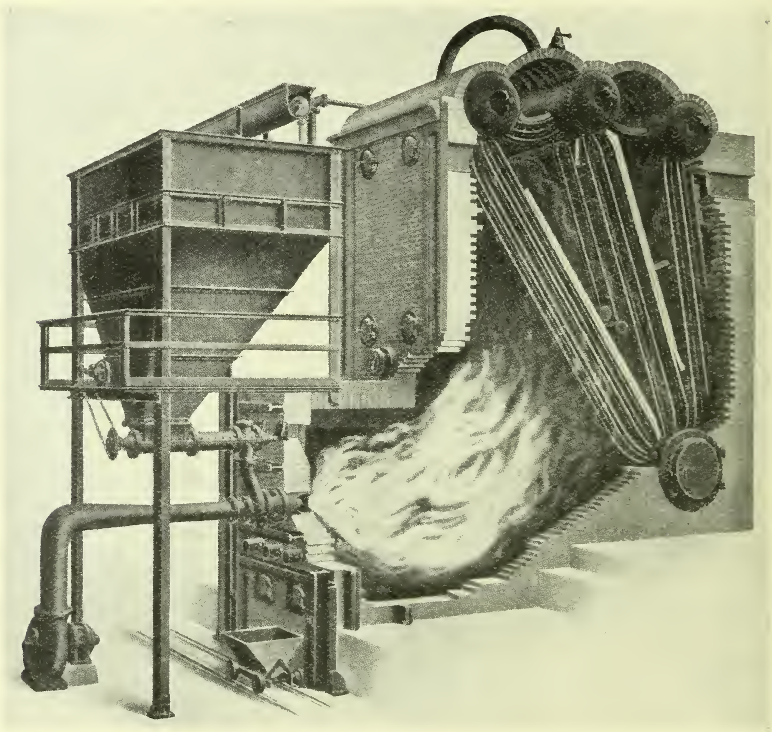


Fig. 12.—Pulverised Coal-fired Stirling Boiler.

suggest that it would be advisable to take out mechanical stokers which are doing good work and substitute dust-firing, since to be successful this would involve considerable and expensive alterations to the existing setting of the boilers, but considers that the advantages of pulverised coal firing are sufficiently arresting to ensure its careful consideration when new installations are contemplated.

So far no work has been carried out with reference to the

dust-firing of the Lancashire type of boiler. That a remarkable saving could be effected is very probable, more particularly

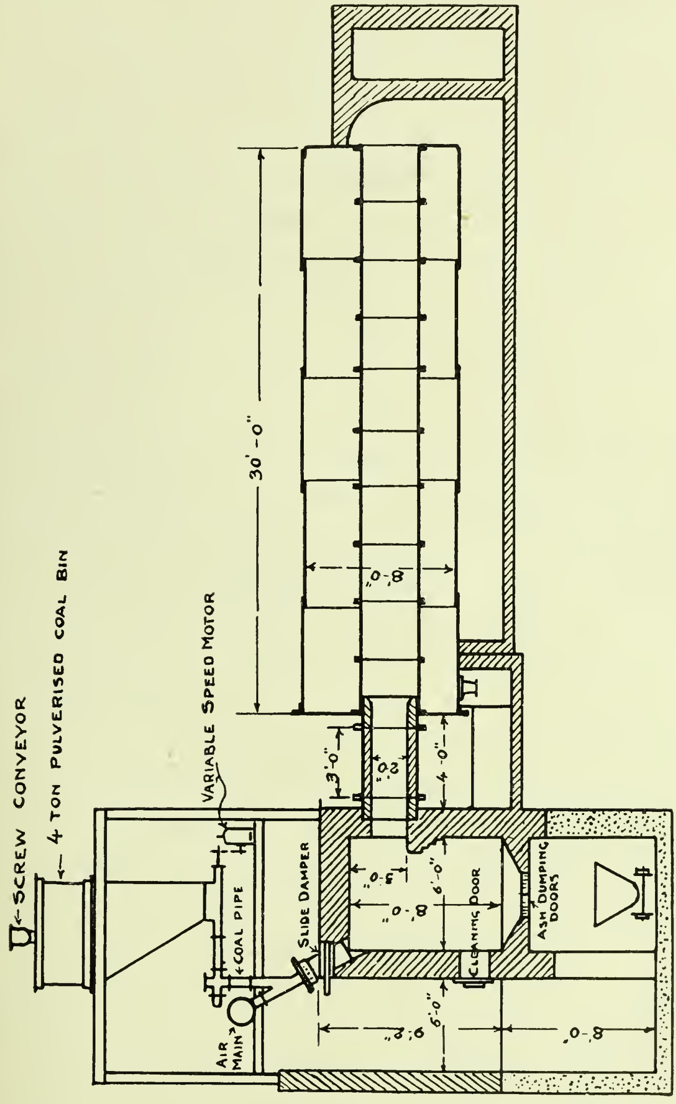


Fig. 13.—Method of firing Lancashire Boiler.

if some of the hand-fired boilers operating under variable load conditions could be converted.

A system of firing with bins at each boiler, as shown in Fig. 13, would take up considerable room in front of the boiler, and in general with existing boilers the available space in this direction is very limited.

Use of Anthracite.—The successful burning of anthracite and other fuels low in volatile content has until quite recently presented a certain amount of difficulty, and it has been the practice to mix a certain percentage of bituminous coal with such fuel. It is now claimed that with finer pulverisation and correct furnace design it is possible to burn such a poor quality anthracite as $2\frac{1}{2}$ per cent. volatile, 20 per cent. ash, with a calorific value of 9000 B.Th.U.

At several collieries in the Pennsylvania district boilers are fired with pulverised anthracite and washery culm. Messrs. Barnhurst and Scheffler, in a paper before the American Society of Mechanical Engineers, June 1919, give particulars of tests on eighteen boiler installations, showing efficiencies from 72 to 85 per cent. Several of the plants were fired with anthracite of various qualities; the plant using Lyttle slush anthracite, calorific value 12,735 B.Th.U., 23·9 per cent. ash, while evaporating 88 per cent. above the normal rating of the boiler, maintained an efficiency of 75 per cent.

These test figures suggest a very efficient way of utilising large quantities of anthracite duff. Also many of the mine tips contain fuel which it might pay to pulverise and burn, since the cost of such fuel would be only that required to transport it to the pulverising plant. The question of the possibility of using the coal dust at present formed in the mines in such quantities must have already occurred to members. Such coal dust is extremely fine, and it would only require to be put through a grinder to secure uniformity and to expose fresh surfaces to oxidation to make it an ideal fuel for furnace work.

At present the danger of a dust explosion underground is combated by covering the layers of dust which exist everywhere by a layer of equally fine stone dust. It might be practicable for mining engineers to withdraw this mixture of coal and stone dust from the mine by a suction method, and then separate the dusts by a winnowing process. Whether it is a practicable possibility or not to utilise the coal dust formed in the roadway for boiler-firing, the coal dust collected at the screens could very easily be utilised for this purpose.

In certain jigging washing plants the very fine dust formed during the screening operation is diverted to cyclone collectors. A plant dealing with 1000 tons of coal per day would in this way collect about 26 tons of fine dust over the twenty-four hours.

This fine dust is often thrown over the washed coal to act as a dehydrating agent. From 26 tons of such dust, if passed through a pulveriser and used for boiler-firing, it would be possible to generate 1000 kilowatts through the twenty-four hours on the basis of 7 lb. water evaporated per lb. of coal, with steam used in a turbine having a consumption of 17 lb. per kilowatt hour.

Application to Iron and Steel Industries.—Up to date the greatest application of powdered fuel other than in the cement industry has been in certain metallurgical operations.

In 1903 the engineers at Lebanon Iron Works, Pennsylvania, noting the use of coal in the cement industry, started experimental work to apply pulverised fuel to heating metallurgical furnaces, and a plant erected in 1905 has been in operation to the present date.

For metallurgical work powdered coal firing will chiefly be compared with producer-gas practice. Each system has its particular sphere of usefulness, and in certain cases the advantages of the one will outweigh those of the other. It

will be noted, however, that the producer system, so far as heat efficiency is concerned, starts with the disadvantage that 15 per cent. of the energy of the fuel is lost in the producer.

It is not proposed to discuss at any length the application of powdered fuel to metallurgical operations, but only to mention briefly the results obtained in several interesting applications.

Perhaps in metallurgical work the most striking instance of the successful use of powdered fuel is its application to puddling furnaces, and its approval by the conservative puddler. The following figures were recently obtained in connection with a turbo-pulveriser firing a puddling furnace at the works of Messrs. Stewarts & Lloyds.

The coal consumption with dust-firing was 14 cwt. per ton of puddled bar produced under ordinary working conditions, as compared with 20 cwt. in the same furnace when hand-fired. The users anticipate that when certain alterations to the furnace are completed a better efficiency will be obtained.

Published figures [1] for a puddling furnace fired with powdered coal operating in conjunction with a waste-heat boiler at the Shelton Iron and Steel Works show an average coal consumption of 12 cwt. per ton of iron, with an evaporation in the waste-heat boiler of 5·3 lb. per lb. of coal fired.

These results certainly confirm the American figures of a gain of 40 per cent. over hand-fired puddling furnaces.

Sheet Furnaces and Annealing Furnaces.—The application to these furnaces appears to be distinctly successful. It is claimed as against hand-firing, that the correct temperature

[1] J. S. Atkinson, *Proceedings of the West of Scotland Iron and Steel Institute.*

can be more easily maintained, and that the loss in actual metal from oxidation, both as regards annealing-boxes

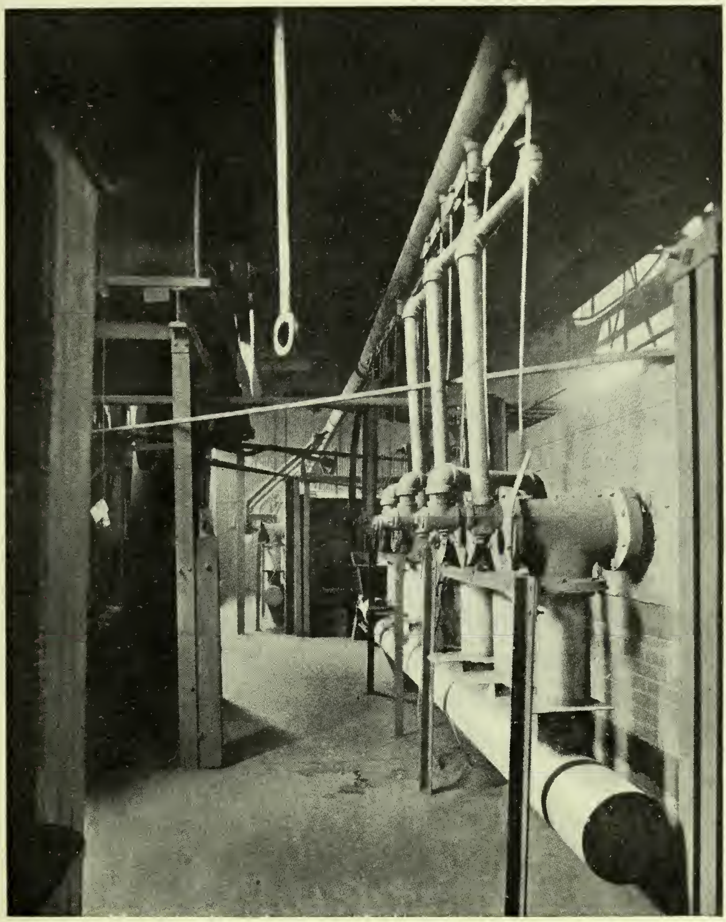


FIG. 14.—TINPLATE ANNEALING FURNACES (HOLBECK SYSTEM).

and the sheets and articles to be annealed, is distinctly reduced.

The comparison in coal consumption per ton of finished plate is 290 lb. as against 350 lb. with hand-fired furnaces. It is found that the ash does not stick to the plates and will

not roll in. Fig. 14 shows the general appearance of a tin-plate annealing furnace fired on the Holbeck system.

Heating Furnaces.—At the works of Messrs. Babcock & Wilcox, Ltd., Renfrew, the furnaces for heating the water-tube headers previous to pressing are fired with powdered fuel, the temperature required for the operation being about 1130° C. (2066° F.).

The following temperatures were taken thirty minutes after starting the furnace :

At the bridge, 1200° C. (2193° F.).
At the centre of hearth, 1190° C. (2142° F.).
On the back wall of furnace, 1120° C. (2016° F.).

The coal consumption per ton of headers heated was 263 lb. This figure, which is about equal to that obtained with efficient gas-firing, has since been bettered. No trouble has been experienced with the ash, which is in the form of a fine powder.

Open-Hearth Furnaces.—In open-hearth work it is of course essential that the coal used should be of good quality and low in ash and sulphur content. Several failures have occurred in the application of powdered coal firing to open-hearth furnaces due to choking up of the chequers with dust, involving the shutting down of the plant.

With finer grinding and considerable alteration in the design and arrangement of the chequers, certain American installations are now proving successful.[1] The average coal consumption is found to be between 500 and 600 lb. per ton of steel ingots.[2]

Reverberatory Copper Furnaces.—The greater portion of the world's output of copper, approximately 1·4 million tons

[1] C. J. Gadd, *Journal of the Franklin Institute*, Sept. 1916.
[2] L. C. Harvey, *Iron and Steel Institute*, May 1919.

per annum, is smelted in America, and published tests [1] show that at the Anaconda Copper Works the output of copper per ton of fuel with dust-firing was 7 tons, as compared with 3·88 tons of copper per ton of coal in hand-fired furnaces.

Reduction of Scaling Loss.—The ability to control easily the furnace conditions in reheating and annealing furnaces results in considerable reduction in loss of metal. The small amount of excess air used in the firing of a reheating furnace, dealing with 168 tons of billets per day for rolling, was considered to account for the saving of 2 per cent. of the metal through reduction in scaling.

In annealing furnaces the life of the annealing-boxes is doubled on account of the ease, as compared with hand-firing, with which a reducing atmosphere can be maintained, thereby avoiding oxidation.

Locomotive Firing.—The application of powdered coal to locomotive firing promises to be most successful, and developments in this direction are likely to take place rapidly. The initial difficulty with regard to its use was the choking of the locomotive boiler tubes with dust and slag, but this has been largely overcome by making the burners as large as possible, thus reducing the velocity with which the coal dust enters the furnace.

Powdered coal is supplied to an enclosed air-tight fuel container on the tender. The screw-feeders to convey the coal to the furnace are driven through gearing by a small steam-engine or turbine which can be run off a steam supply in the cleaning-house until sufficient steam pressure, say 15 to 20 lb., is raised. The air supply is obtained at a few inches W.G. from a small turbine-driven fan.

[1] L. V. Bender, *American Institute of Mining Engineers*, Jan. 1915.

It will be evident that a successful dust-fired locomotive would possess distinct advantages, chief of which may be mentioned :

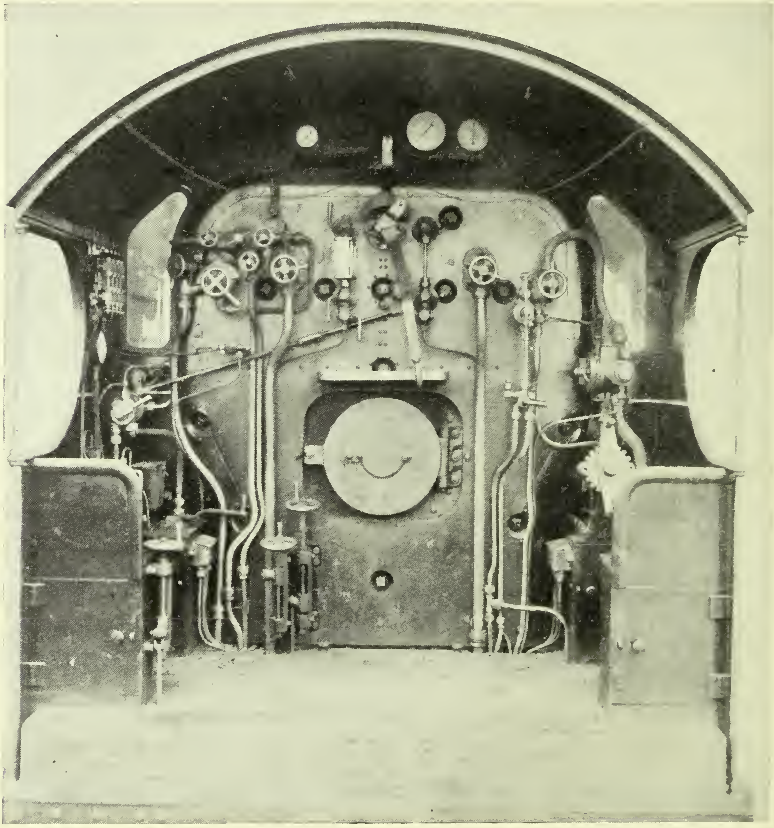


FIG. 15.—FOOTPLATE, ENGINE NO. 422.

(1) Sustained boiler power.
(2) Automatic firing.
(3) Reduction of heat losses.
(3) Easy fuelling.
(5) Ability to use inferior fuel.

It is probable that not less than one-fourth of the annual

coal consumption of a locomotive is used to maintain fires when the engine is standing. Again, the loss in locomotive firing due to cinders and sparks is estimated as 8 per cent. of the total fuel used. Both these losses would be obviated under dust-firing conditions, as also the loss in vaporising the moisture in ordinary fuel. Such considerations lead to an estimate of about 25 per cent. as the probable ultimate saving in coal consumption due to firing with powdered coal.

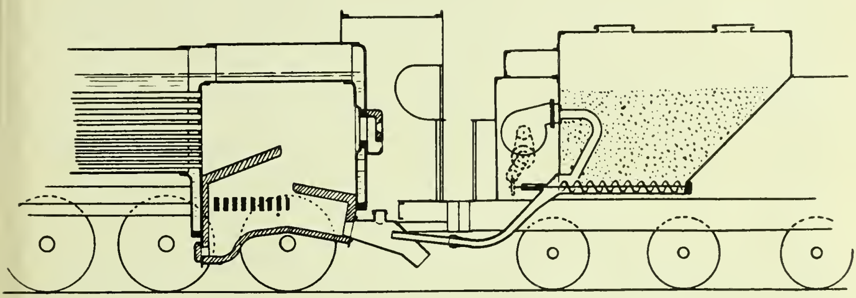


Fig. 16.—Locomotive Boiler fired with Powdered Coal

In view of the interest taken in the successful running of a locomotive fired with oil fuel on one of our main lines, it is particularly interesting to note that the 'Great Central Railway have now two locomotives fired with coal dust.' A view of the cab of one of these locomotives is shown in Fig. 15, and Fig. 16 is a diagram showing the essential features of the system.

Through the courtesy of Mr. J. G. Robinson, the chief mechanical engineer of the railway, and Messrs. The United Oil and Coal Corporation, Ltd., it is possible to state that the experimental results to date are satisfactory and justify the following conclusions :

(1) Pulverised fuel containing a high percentage of ash can be efficiently burned with properly designed apparatus.

(2) Coal in a pulverised condition gives a higher evaporative efficiency than ordinary fuel.

(3) The use of pulverised coal makes it possible to attain a higher maximum steam output.

(4) The cost of maintenance with powdered fuel is less because a more equable temperature can be maintained in the fire-box, resulting in reduction of expansion and contraction stresses causing leakage of tubes and breakage of stays.

(5) Locomotives can be readily adapted for the use of powdered coal, and there is no danger attending its use as fitted with the Robinson arrangement.

It is probable that to obtain maximum efficiency with powdered coal the design of locomotive fire-boxes and boilers must be modified, and to this end Mr. Robinson is at present experimenting with a locomotive type boiler having an exceptionally large fire-box capacity.

The fuelling of locomotives could be rapidly performed at pulverising-houses situated at convenient junctions, and would involve no more trouble than taking in water. Fig. 17 is a photograph of one of the Great Central locomotives taking fuel from the pulverising plant supplied by the Powdered Fuel Co., Westminster.

The economic aspect of the powdered fuel firing of locomotives has been quickly realised by countries which have had to import high-grade coal, while possessing natural supplies of low-grade fuel, lignite, &c. In Brazil on many of the railway lines powdered coal firing with native coal is now in successful operation.

Colliery companies and large works using sufficient coal to warrant the expense of a pulverising plant might with

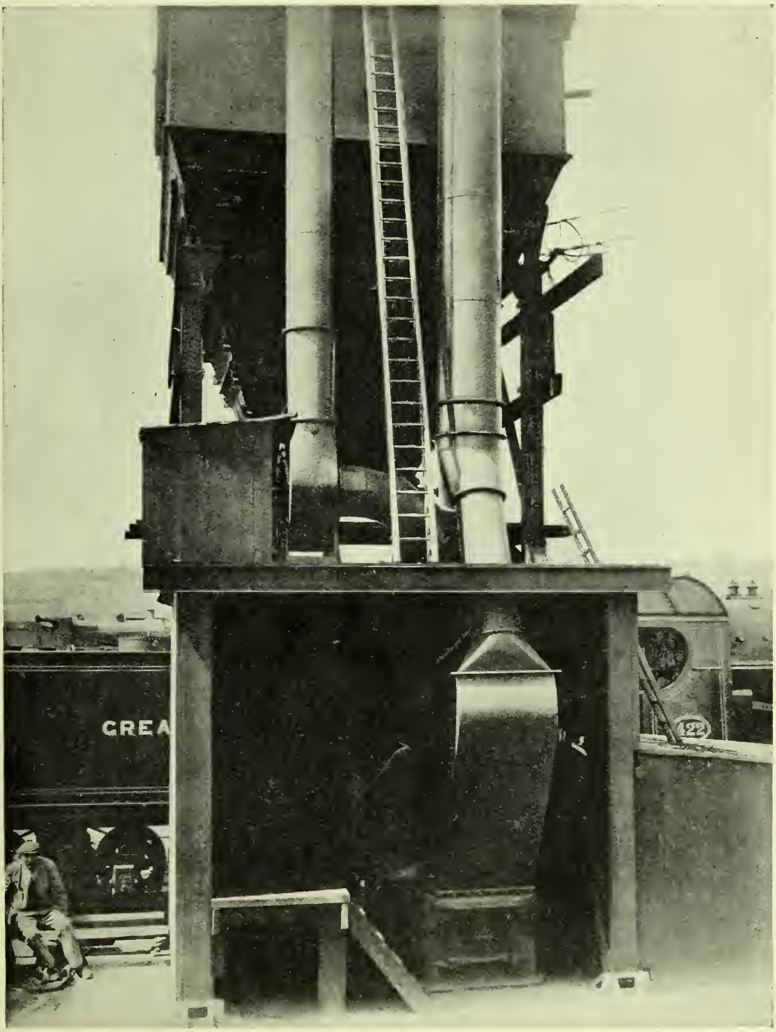


Fig. 17.—Locomotive taking in Fuel from Pulverising Plant.

advantage run their own locomotives on low-grade quality coal.

Marine Propulsion.—The application of coal-dust firing to marine boilers is difficult on account of the danger of caking and spontaneous combustion in the bunkers of ocean-going

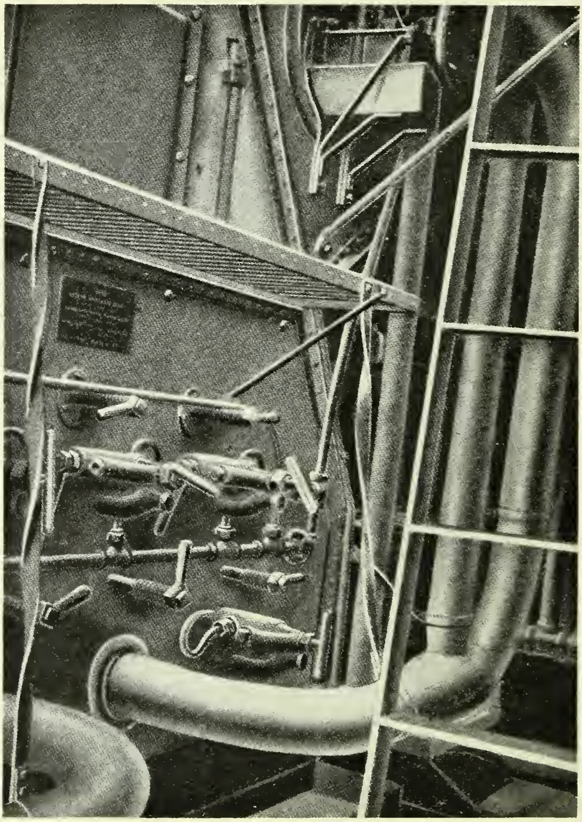


Fig. 18.—Steamship Boiler fitted with Pulverised Coal-burning Equipment.

ships. For ships on a definite short sea route, such as Channel steamers, it would be possible to fill the bunkers from a pulverising station ashore. In such a case the decided advantages of pulverised fuel as regards stokehold conditions and boiler efficiency could be secured. On the other hand, it must be noted that bunker capacity with powdered coal

would be reduced by 20 per cent., since powdered coal weighs 35 lb. per cubic foot, whereas ordinary bunker coal weighs about 45 lb. per cubic foot.

Experiments are being carried out in this country with regard to the practicability of firing on board, but in the opinion of the writer the general use of powdered fuel for marine propulsion is more likely to develop in the future from its use as a fuel for internal combustion engines. Experimental work has already been carried out in this direction, but the present difficulty in using an explosive mixture of air and coal instead of oil in the cylinder of an oil engine is due to the cutting action of the ash on the valves.

Colloidal Fuel.—This term is applied to a mixture of oil and powdered coal having a calorific value per unit volume equal to the original oil. This fuel is an attempt to find a satisfactory and cheaper substitute for oil. The usual mixture consists of about 70 per cent. oil with 30 per cent. powdered coal in suspension.

With oil at £12 per ton and coal at, say, £3 per ton, it will be seen that the cost of 1 ton of colloidal fuel is appreciably less than oil fuel, even when an allowance of 7*s.* per ton is made for interest and depreciation on necessary plant.

To overcome the difficulty of maintaining the powdered coal in suspension without mechanical agitation by means of paddles, a certain fixative has been invented which enables the coal to be kept in suspension in the oil for a month or so without any serious separation taking place. This fixateur, as it is termed, is introduced to the extent of less than 2 per cent., and in itself is almost completely combustible. Average calorific values for colloidal fuel and oil fuel would be 17,300 and 18,300 B.Th.U. per lb.

A series of tests on colloidal oil and powdered coal have been carried out with satisfactory results on the U.S. patrol

ship *Gem*, and Fig. 18 shows a view of the stokehold as arranged for firing with powdered coal.

In concluding this brief survey of the potentialities of powdered fuel the writer would like to thank the firms mentioned for information supplied, and also his colleague, Mr. R. M. Metcalfe, for help in the preparation of diagrams and lantern slides.

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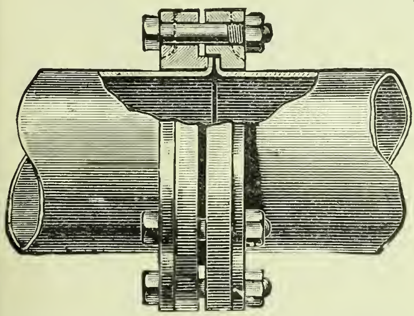

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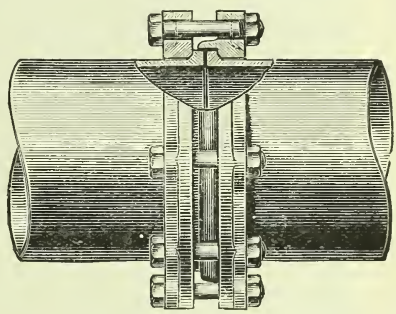

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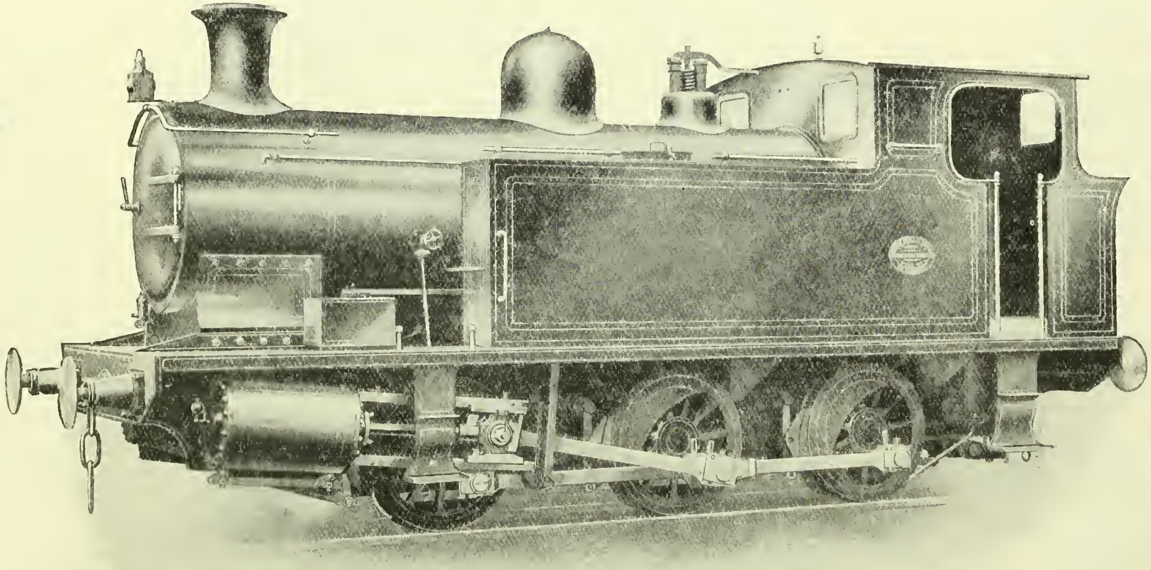

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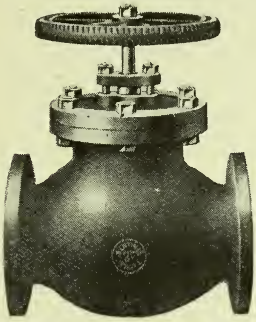

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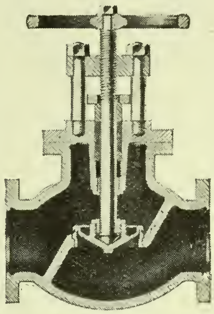

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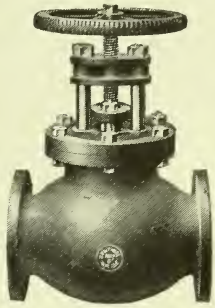

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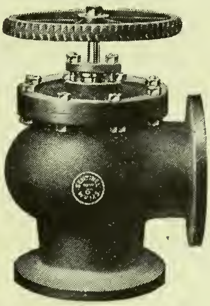

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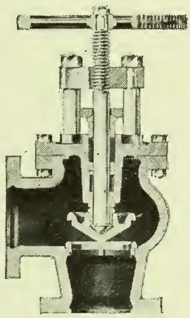

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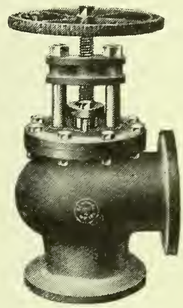

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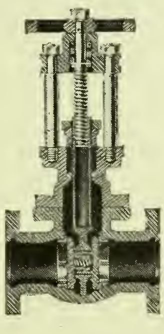

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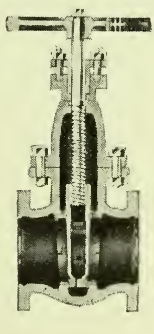

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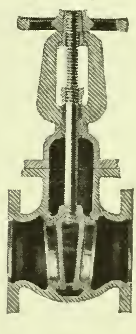

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VOL. XXXVII.] [No. 2

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63RD ANNUAL GENERAL MEETING, MARCH 17TH, 1921 AND SPECIAL GENERAL MEETING, APRIL 28TH, 1921, AT CARDIFF.

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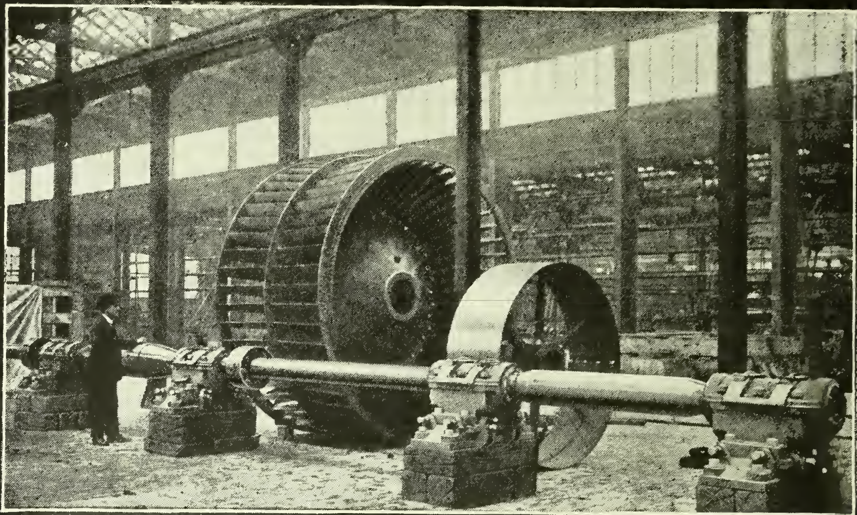

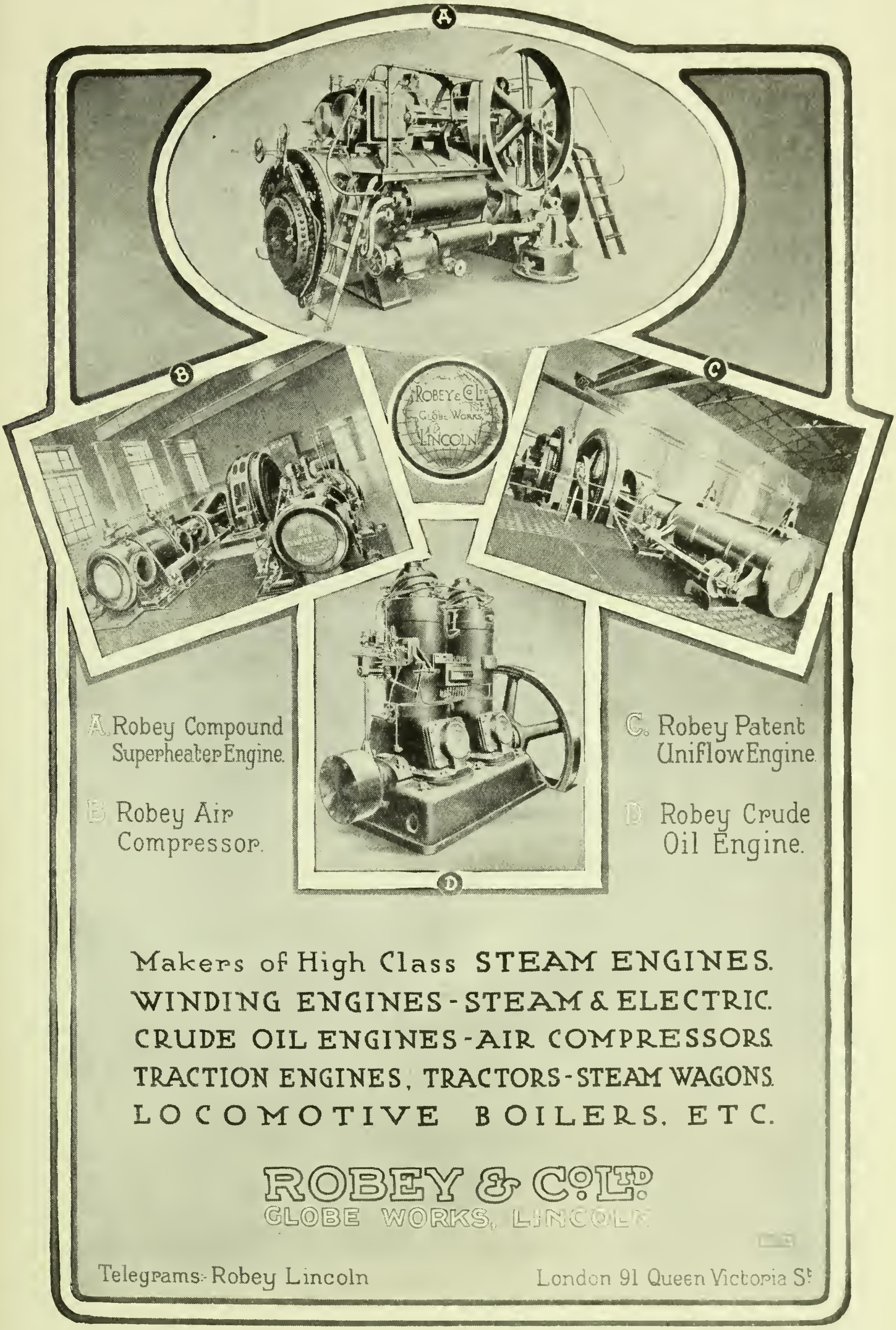

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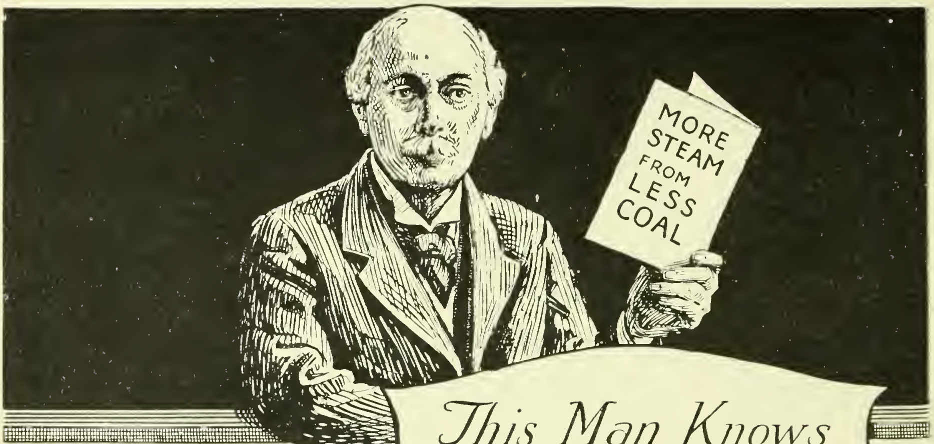
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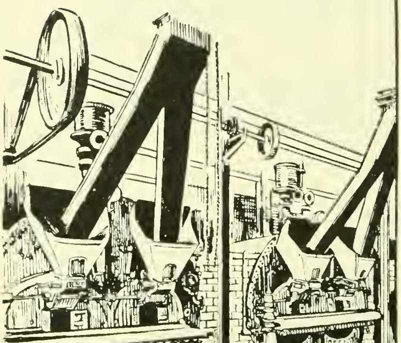

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	SESSIONS	
Menelaus, William, M.Inst.C.E. ...	1857–58 ; 1864–65 ...	(Deceased)
Rogers, Ebenezer	1858–59	(Deceased)
Clark, William Southern	1859–60	(Deceased)
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Evans, Thomas	1862–63	(Deceased)
Basset, Alexander, M.Inst.C.E. ...	1863–64	(Deceased)
Martin, George	1865–66 ; 1866–67 ...	(Deceased)
Bedlington, Richard	1867–68 ; 1868–69 ...	(Deceased)
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Steel, T. Dyne, M.Inst.C.E. ...	1871–72 ; 1872–73 ...	(Deceased)
Brown, Thomas Forster, M.Inst.C.E.	1873–74 ; 1874–75 & 1891–92 ; 1892–93	(Deceased)
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Deakin, Thos. Hedges, M.Inst.C.E.	1905–06 ; 1906–07	
Wight, William Dundas	1907–08 ; 1908–09 & July 1911 to Dec. 1911	
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Stewart, Wm.	1916	
Bramwell, Hugh, O.B.E.... ...	1917	
Tallis, John Fox	1918	
Dawson, Edward, M.I.Mech.E. ...	1919	
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Jordan, Henry K., D.Sc., F.G.S.	1897–98, 1898–99.
Evens, Thomas, M.Inst.C.E.	1899–00, 1900–01.
Hann, E. M., M.Inst.C.E.	1903–04, 1904–05.
Deakin, T. H., M.Inst.C.E.	1905–06, 1906–07.
Wight, Wm. D.	1907–08, 1908–09 & July to Dec. 1911.
Galloway, W., D.Sc., F.G.S., F.I.D.	1912.
Wales, Henry T.	1914.
Stewart, Wm.	1916.
Bramwell, Hugh, O.B.E.	1917.
Tallis, John Fox	1918.
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Lewis, J. Dyer	1920.

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1905.—A First Prize was awarded to Mr. W. Waplington for his Paper "Description and Design of the Best Arrangements of Equipment of the Bottom, with a Radius of 400 yards, of a Pair of Pits to be Upcast and Downcast Respectively."

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1913.—Special Prize awarded Mr. Will Gregson for his Paper "The Most Approved Methods of Hauling the Coal from the Working Faces to the Pit Bottom."

1914.—Special Prizes awarded Messrs. J. Williams and S. R. Cound for their Papers on "How to Improve Welsh Tinplate Rolling-mill Practice."

1918.—A First Prize was awarded to Mr. W. T. Lane, and a Second to Mr. W. H. Casmey, for their Papers on "Fuel Economy in Power Production (or Utilisation of Waste Heat)."

1920.—A First Prize was awarded to Mr. R. C. Morgan for his Paper "Causes of Subsidences and the best Safeguards for their Prevention."

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Note. — Mr. Knight was unable to take up the Scholarship he had won, and an honorarium of £10 was granted him by the Council, also a Certificate to the effect that he had won the Scholarship.

1919-21.—An EXHIBITION of £13 (plus a bonus of £15) per annum, awarded to Mr. E. G. Davies, Cardiff. (Won in 1915.)

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CHANGE OF RESIDENCE.

The Secretary would be obliged by Members notifying to him any alteration in their addresses at the earliest date.

INSTITUTE BUILDING.

The Institute, Park Place, Cardiff, is open for the use of Members on Week-days from 10 a.m. to 5 p.m.

The New Library is now open for the use of Members, and the technical journals and other periodicals will be found on the tables in that room, instead of in the Council Chamber.

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(Founded in 1918 by Mr. H. Spence Thomas for the encouragement of the Members of the Associations of Students of the Institute.)

The interest on £1,000 5 per cent. War Loan Stock shall be devoted to the Scholarship.

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The Council of the Institute shall award the Scholarship upon Reports presented for its consideration by the Heads of any of the above Colleges, Schools, or Institutions, on the completion of one year's study by any student.

The College, School, or Institution shall present an annual report to the Council on the work and progress of the Scholar to whom the Scholarship shall have been awarded, and the Council retains the right of withholding or cancelling the Scholarship, if in its opinion the progress of the Scholar is unsatisfactory.

In the award of the Scholarship the professional knowledge and practical experience of the candidate shall be taken into consideration.

No candidate will be elected to the Scholarship until he has satisfied the Council that his physical condition is satisfactory.

The Scholarship shall be awarded for a term of one, two, or more years in the discretion of the Council. The Scholar to briefly report at the end of each year upon the work accomplished.

The Council reserves the right to withhold the Scholarship if no candidate of sufficient merit presents himself.

1919–1921. The Spence Thomas Scholarship of £50 per annum was awarded to Mr. William John Gilbert, Nantyglo, for a period of three years, tenable at the School of Mines, Treforest.

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South Wales Institute of Engineers' Scholarship in Engineering.

A Scholarship of the value of £70 per annum, tenable in the University College of Swansea for three years, will be offered for competition by the Council of the South Wales Institute of Engineers at the Entrance Scholarship Examination, which will be held at the College, Mount Pleasant, Swansea, on September 12, 1921.

The following are the special regulations and conditions attached to the award of the Scholarship:

1.—The Examination will be conducted by the College at the same time as the Entrance Scholarship Examination, and the Council of the College will submit the conclusions of the Senate to the Council of the Institute, who, after consideration of the Senate's report, will select the scholar.

2.—The College will present a report at the end of each College Term on the work and progress of the scholar, and the Council of the Institute retains the right of withholding the Scholarship if, in its opinion, the progress of the student is unsatisfactory.

3.—The scholar will be expected to have completed the Matriculation Examination of the University of Wales, or some equivalent Examination, but this qualification may be waived in cases where there is evidence of *exceptional* ability in professional subjects. In the latter case, however, the scholar will be required to pass the Matriculation Examination, or some equivalent Examination, at or before the end of his first year in College, and in such a case the Institute will consider the advisability of granting an Exhibition of lesser value for his first year or of extending the Scholarship for a fourth year.

In the case of a candidate who gives evidence of exceptional ability in his scientific and professional subjects, but who has not passed the Matriculation Examination or its equivalent, and who does not wish to pass such an Examination at the end of his first year, thereby enabling him to prepare for the degree of B.Sc. in Engineering in the University of Wales, the Council is prepared to allow the holder of the Scholarship to dispense with Matriculation, provided he submits a suitable scheme of research, to be carried out under the direction of the Professor of Engineering, and appears to possess the necessary qualities for successfully undertaking such research.

4. In the award of the Scholarship the practical and professional experience of the candidate will be taken into consideration.

5.—The holder of the Scholarship will, during his tenure thereof, be admitted into the privileges of a Student of the Institute.

6.—In the Examination the following subjects are obligatory:

English Essay (1 paper).
Pure Mathematics (1 paper).
Applied Mathematics (1 paper).
Applied Mechanics (1 paper).

In addition, the candidate must take two and not more than two of the following subjects:

(*a*) Chemistry (1 paper).
(*b*) Physics (1 paper).
(*c*) Geology (1 paper).
(*d*) Heat Engines (1 paper).
(*e*) Geometric and Engineering Drawing (1 paper).
(*f*) Electrical Technology (1 paper).

7.—The age of the candidate on April 1 prior to the date of the Examination must not exceed 25 years. In the case of a candidate who intends to pursue a scheme of research, this restriction need not be held to apply.

8.—No candidate will be elected to the Scholarship until he has satisfied the Council of the Institute that he is of sound bodily constitution. The Council also reserves the right to suspend the Scholarship should the physical condition of the holder subsequently become unsatisfactory.

9.—The Council of the Institute reserves the right of withholding the Scholarship if no candidate of sufficient merit presents himself.

10.—Every candidate must be a British subject.

11.—Every candidate must sign a declaration of his intention to enter some branch of the Engineering profession. The holder of the Scholarship will be expected to devote the whole of his time and energy to the pursuance of a course of study or research approved by the College Authorities. He may not become a candidate for any other Scholarship, exhibition, or remunerative position, unless special permission has been sought and obtained from the Council of the College and the Council of the Institute.

Intending candidates may obtain from the undersigned the General Regulations affecting the Entrance Scholarship Examination, and a printed Form of Application for admission to the Examination for the Scholarship in Engineering, which must be returned to the Registrar properly filled in on or before August 1, 1921, together with a certificate of birth and testimonials of good conduct.

EDWIN DREW, Registrar.

University College Offices:
Dumbarton House,
Bryn-y-mor Crescent, Swansea.

ADVERTISEMENTS.

CONTENTS.

No. 2. VOLUME XXXVII., issued May 24th, 1921, price 5s.

PROCEEDINGS.

Sixty-third Annual General Meeting, March 17, 1921.

THE Sixty-third Annual General Meeting of the Institute was held at the Institution on Thursday, March 17, 1921, the President, Mr. W. Forster Brown, M.Inst.C.E., being in the chair.

The Minutes of the preceding General Meeting held on January 28, 1921, were read and confirmed.

Election of Members.

The following candidates for admission to the Institute were declared duly elected :

As Members.

ATKINSON, ROBERT WILLIAM, B.Sc. . Cardiff.
BUNDY, WALLACE SAMUEL . . . Swansea.
DAVID, WILLIAM THOMAS, M.A. (Cantab.), D.Sc. (Wales), A.M.Inst.C.E. . Cardiff.
DUNN, GORDON CLEMENT, M.I.Min.E. . Tunbridge Wells.
HOWELLS, RICHARD . . . . Gwaun-cae-Gurwen.
INGLEDEW, HUGH MURRAY . . Cardiff.

Jones, John Walmsley . . . Port Talbot.
Larkworthy, Ralph . . . Pontypridd.
Lewis, Richard Lester . . . Pontymister.
McCall, Thomas Lockhart . . Largs, Ayrshire.
Rees, William David G. . . . Skewen.
Uttley, James Arthur, M.Sc., A.M.Inst.C.E. . . . . Rumney, near Cardiff.

As Associate Members.

Morgan, Jacob Thomas . . . Nelson, near Cardiff.
Richards, Sidney Christmas . . Cardiff.
Ruse, William Alfred . . . Swansea.

As Associate.

Thomas, Sydney . . . . Hengoed.

East Glamorgan Students' Association of the Institute.

As Associates.

Davies, Thomas Isaac . . . Treorchy, Glam.
Evans, Richard Kenneth . . Cardiff.
Lewis, Anthony . . . . Mardy, Glam.
Rees, William Henry . . . Llanwit Vardre, Glam.
Smith, William John . . . Pen-y-cae, Port Talbot.

As Student.

Williams, Haydn . . . . Abercanaid, Merthyr Tydfil.

Monmouthshire Students' Association of the Institute.

As Associates.

Benson, Trevor Russell	Crosskeys, Mon.
Blacker, Thomas Henry	Abertillery, Mon.
Creese, David	Abersychan, Mon.
Dando, Alfred Price	Blackwood, Mon.
Davies, Brinley	Nantyglo, Mon.
Durbin, Elias J.	Risca, Mon.
Harris, Cyril Samuel	New Tredegar, Mon.
Harris, Ivor Charles	New Tredegar, Mon.
Harvey, Godfrey	Pontnewynydd, near Pontypool, Mon.
John, Joseph	Brynmawr, Breconshire.
Keen, Ernest Edward	Troedyrhiw, near Merthyr Tydfil.
Lewis, Evan Thomas	near Pengam, Mon.
Martin, Thomas	Abersychan, Mon.
Milsom, Francis Joseph	Pontnewynydd, Pontypool, Mon.
Parfit, William George	Pontypool, Mon.
Powell, Cecil Baden	Abertillery, Mon.
Prosser, Alfred Raymond	Abertillery, Mon.
Protheroe, William	Blaina, Mon.
Silcox, Horace	Pontypool, Mon.
Vodden, Charles Edwin	Pengam, Mon.

As Students.

Calloway, John Donald	Brynmawr, Breconshire.
Corfield, Leslie Charles	Abercarn, Mon.

Curtis, Haydn Cyril . . .	Ystradmynach, near Cardiff.
Davies, Walter John . . .	Abertillery, Mon.
Griffiths, John	Argoed, Mon.
Harris, Reginald Charles . .	Abercarn, Mon.
Jenkins, John	Blackwood, Mon.
Jones, Isaac John Blackwell . .	Ebbw Vale, Mon.
Jones, Walter Thomas . . .	Tredegar, Mon.
Leigh, Cyril	Abertillery, Mon.
Morgan, Rowland Henry . .	Tredegar, Mon.
Nicholas, Walter David Percival .	Newbridge, Mon.
Powell, David William . . .	Pengam, Mon.
Price, Emrys	New Tredegar, Mon.
Rees, Harold	Blackwood, Mon.
Tolfree, Robert W.	Tredegar, Mon.
Trenhail, William	Abertillery, Mon.
Veysey, J. Archie	Risca, Mon.
Vines, David John	Rhymney, Mon.
Williams, Harold	Abersychan, Mon.
Williams, Rowland Joseph . .	Aberbeeg, Mon.
Williams, Wilfred Haydn . .	Abertillery, Mon.

Financial Statement.

The President.

The President moved the adoption of the Financial Statement and Balance Sheet for the year ended December 31, 1920, which had been printed and circulated amongst the members.

Mr. David E. Roberts.

Mr. David E. Roberts seconded, and the motion was carried.

Election of Auditors.

The President. Mr. David E. Roberts.

On the motion of the President, seconded by Mr. David E. Roberts, Messrs. McDonald and Rees were reappointed auditors for the ensuing year.

Election of Secretary.

The PRESIDENT said, as members were aware, it was necessary to elect the Secretary annually. He had much pleasure in proposing the re-election of Mr. Martin Price. No words of his were needed to recommend this resolution. In Mr. Price they had a very able and energetic Secretary, whose heart was bound up in the success of the Institute; and no President could have a more helpful official. (Applause.) **The President.**

Dr. H. K. JORDAN said he would like to have the privilege of seconding the President's motion. He had known the Secretary since he was a youth, and had watched his career with pleasure since he followed in the Secretaryship the late Mr. Jones Price, his talented and greatly respected father. The son had inherited the qualities of the father, and was serving the Institute well and with credit to himself. **Dr. H. K. Jordan.**

The motion was adopted with acclamation.

Lewis Prize Competition, 1920.

The PRESIDENT said members would recall that in 1895 the Lewis Prize Fund was founded by the late Lord Merthyr for the paper adjudged by the Council to be the best contributed to the Institute during the year on subjects relating to practical engineering. It was particularly pleasing to him (the President) to know that the winner of the first Lewis Prize for the year 1920 was a student at the School of Mines, Treforest, and a Member of the East Glamorgan Association of Students of the Institute, for his paper on 'Causes of Subsidence and the Best Safeguards for their Prevention.' In handing over the cheque for £20 to Mr. R. C. Morgan he had warmly to congratulate him upon having submitted such **The President.**

The South Wales Institute of Engineers.

FINANCIAL STATEMENT FOR YEAR ENDED 31st DECEMBER, 1920.

Dr. Receipts.	£	s.	d.	£	s.	d.
To Balances December 31, 1919 :—						
,, Lloyds Bank, Ltd., Current Account	16	15	2			
,, ,, ,, on Deposit, Building Redemption Fund	24	0	1			
,, ,, ,, on Deposit, Library Equipment Fund	17	7	6			
,, ,, ,, on Deposit, General Deposit	95	8	9			
,, Petty Cash in Hand	0	8	0			
				153	19	6
,, Members' Subscriptions :						
Current Session, 1920	1,586	16	0			
Arrears	77	14	0			
In advance for Session 1921	71	8	0			
				1,735	18	0
,, Sale of Institute 'Proceedings'				19	1	1
,, Sale of 'Lectures on Mining'				0	8	2
,, Sale of Papers :—'The South Wales Coal Field'				17	17	0
,, Advertisements in 'Proceedings'				456	3	9
,, Advertisements in 'Students' Journals'				84	16	3
,, Institute Buildings, Maintenance Charges :—						
,, Mon. and South Wales Coal Owners' Association—Proportion to June 30, 1920				926	4	3
,, Fees				82	16	6
,, Sale of Furniture, Swansea Room				45	0	0
,, Interest, etc., from Investments :—						
,, Lewis Prize Fund	16	7	7			
,, Building Redemption Fund	29	2	6			
,, Library Equipment Fund	3	0	10			
,, General Investment Fund	165	2	4			
,, Spence Thomas Scholarship Fund	41	13	8			
				255	6	11
,, Balances at December 31, 1920 :—						
,, Lloyds Bank Ltd., Current Account	79	9	9			
,, Petty Cash Account	7	18	5			
				87	8	2
				£3,864	19	1

Cr. Payments.	£	s.	d.	£	s.	d.
By Cost of Proceedings				988	4	5
,, Printing and Stationery				323	9	6
,, Reporting				59	6	4
,, Secretary's Salary				400	0	0
,, Postages and Telegrams				143	13	9
,, Swansea Room, Rent, etc.				40	7	11
,, Wages of Office Staff				54	0	0
,, Lantern Hire and Lanternist				4	9	6
,, Bank Charges				20	13	6
,, Summer Meeting in Lake District, Cost to Institute				64	4	8
,, Institute Annual Dinner, Cost to Institute				36	4	6
,, Institute Gold Medal				19	15	0
,, Incidentals				6	13	0
,, Audit Fees, Sessions 1918 and 1919				21	0	0
,, Scholarship and Exhibitions :—						
Myrddin David, Institute Scholar	85	0	0			
E. Gordon Davies Exhibition	42	0	0			
J. S. Caswell Exhibition	30	0	0			
				157	0	0
University College, Cardiff Students' Association, Prizes, etc.				22	8	10
'Students' Journals,' Cost of Printing				123	2	6
,, Students' Associations, Cash Advances to Secretaries :—						
W. T. Lane, East Glamorgan Association	40	0	0			
R. J. Currie, Monmouthshire Students' Association	10	0	0			
J. L. Roach, Cardiff College Association	15	0	0			
				65	0	0
,, Spence Thomas Scholarship :—						
W. J. Gilbert, Scholar	50	0	0			
Advertising Scholarship	11	14	0			
				61	14	0
,, Sale of Papers :—						
'The South Wales Coal Field'				14	14	0
,, Dawnay Bequest, Legal Stamps				0	12	7
,, Institute Buildings, Maintenance :—						
Ground Rent, less Tax	35	0	0			
Insurance	25	5	2			
Rates and Taxes	338	7	2			
Lighting and Heating	379	4	11			
Repairs	47	18	8			
Caretakers' Wages, etc.	150	12	0			
Extra Cleaning	32	7	0			
Sundry Stores, Cleaning Requisites, etc.	37	11	7			
				1,046	6	6
,, Balances December 31, 1920 :—						
Lloyds Bank, Ltd., Deposit, Building Redemption Account	53	2	7			
,, Deposit Library Equipment Account	20	8	4			
,, ,, General Deposit Account	7	0	9			
,, ,, Lewis Prize Fund	67	17	9			
,, ,, Spence Thomas Scholarship	43	9	8			
				191	19	1

BALANCE SHEET, 31st December, 1920.

LIABILITIES.

	£	s.	d.
Sundry Creditors	27	6	11
Due to Lloyds Bank, Ltd., Current Account	79	9	9
Members' Subscriptions, Paid in Advance for 1921	71	8	0
Lewis Prize Fund, per contra	567	17	9
Building Redemption Fund, per contra	871	19	10
Library Equipment Fund, per contra	70	8	4
Spence Thomas Scholarship Fund, per contra	1,043	9	8
Institute Deposit Account	481	15	6
Capital Account, Balance, being Excess of Assets over Liabilities	17,533	17	5
	£20,747	13	2

ASSETS.

	£	s.	d.	£	s.	d.
Cash at Lloyds Bank, Ltd., General Deposit Account				7	0	9
Members' Subscriptions in Arrear				297	10	11
Sundry Debtors				44	13	9
Stock of 'Proceedings,' Nominal Value				20	0	0
Stock of 'Lectures on Mining,' Nominal Value				10	0	0
Invested Funds :—						
£2,000 Cardiff Railway Co. 3 % Deb. Stock at Cost	2,141	19	0			
£1,400 War Stock, 1929–47, 5 % at Cost	1,321	16	1			
£750 4 % Funding Stock 1960–90 at Cost	600	0	0			
				4,063	15	1
Lewis Prize Fund :—						
£243 Barry Railway Co., 3 % Deb. Stock at Cost; £253 Cardiff Railway Co., 3 % Deb. Stock at Cost	500	0	0			
Cash on Deposit, Lloyds Bank, Ltd.	67	17	9			
				567	17	9
Building Redemption Fund :—						
£150 Cardiff Railway Co., 3 % Deb. Stock at Cost	119	15	0			
£390 Rhymney Railway Co., 4 % Pref. Stock at Cost	379	2	3			
£250 War Stock, 1929–47, 5 % at Cost	240	0	0			
£100, 4 % Funding Stock, 1960–90 at Cost	80	0	0			
Cash on Deposit, Lloyds Bank, Ltd.	53	2	7			
				871	19	10
Library Equipment Fund :—						
£50, 5 % War Stock, 1929–47 at Cost	50	0	0			
Cash on Deposit at Lloyds Bank, Ltd.	20	8	4			
				70	8	4
Spence Thomas Scholarship Fund :—						
£1,250, 4 % Funding Stock, 1960–90 at Cost	1,000	0	0			
Cash on Deposit, Lloyds Bank, Ltd.	43	9	8			
				1,043	9	8
Institute Building :—						
Cost, exclusive of Furniture				9,295	2	7
New Library Building :—						
Cost, exclusive of Furniture				4,455	14	6
				£20,747	13	2

We have examined the Accounts and Balance Sheet with the Books and Vouchers of the Institute, and have obtained all the information and explanations we have required. We report that in our opinion the foregoing Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state of the Institute's affairs as at 31st December 1920, according to the best of our information, and explanations given us, and as shown by the Books.

We have inspected the Securities and verified the Bank Balances and Investments standing in the name of the Institute.

Cardiff,
March 7th, 1921.

McDONALD & REES,
Auditors.

The President. a well-considered Paper, and to wish him a career of distinction, of which he gave good promise.

Dr. Jordan. Dr. Jordan (to the recipient): I also congratulate you, young sir.

Lewis Prize Competition, 1921.

The subject selected for the Lewis Prize this year is—'Improved Mechanical Methods for Bringing Coal from Long Distances Underground in view of the Necessity for Increased Output.'

Notes on an Outburst of Gas and Dust at the Ponthenry Colliery.

By George Roblings.

(Paper, *vide* Proceedings, Vol. XXXVI., No. 2, p. 423; Discussions, p. 432, and Vol. XXXVII., No. 1.)

The discussion on this paper was resumed.

The President. The President said some written communications had been received, and they would be incorporated in the 'Proceedings.' To these Mr. Roblings would have an opportunity of writing his reply, also to be inserted in the next 'Proceedings.'

Mr. B. F. Kerridge. Mr. B. F. Kerridge, H.M.I.M., wrote:

After reading Mr. Roblings' very interesting and instructive paper and hearing the discussion thereon at the last meeting it has occurred to me that a brief description of a somewhat similar outburst, which took place at Bryn Colliery some years ago, might possibly be of interest.

The outburst to which I refer was on a somewhat smaller scale than that which took place at Ponthenry, and differs from it inasmuch as it occurred in a cross-measure drift,

Mr. B. F. Kerridge.

and not in a coal heading, but its bearing upon such questions as the use of electric safety lamps appears identical.

Bryn Navigation Colliery is situated almost on the line of the Anticlinal and the measures are much disturbed.

When the outburst occurred a pair of cross-measure drifts, dipping 18 inches per yard, had been driven for some considerable distance through the steam coal measures which had been contorted into a series of anticlinal and synclinal folds.

The two drifts were connected at intervals by cross-cuts for the purpose of ventilation, the face of the intake drift being some forty or fifty yards below the bottom cross-cut, and the face of the return drift rather less.

A round of holes was fired in the leading (intake) drift by the firemen who stood, with the workmen and myself, at the return end of the cross-cut. Immediately after the shots exploded a very heavy and sustained rumble was heard which was thought to have been caused by a heavy fall over the drift timber. A few seconds later the lamps commenced to go out one after another, in consequence of which everyone made for the next cross-cut, some 150 yards up the drift. Fortunately all were able to reach this before the atmosphere in the return drift became irrespirable, and this was probably due to the gas from the intake drift having to pass through a 12-inch pipe in the cross-cut door to reach the return drift.

The two drifts were very amply ventilated owing to the fact that no other places were working at the colliery, but, in spite of this, it was not until the next day that the intake end of the bottom cross-cut could be reached, the gas having forced its way up the intake against the full air current.

After the gas cleared the intake drift was found to have been filled with coal dust for many yards to within a few inches

Mr. B. F. Kerridge.

of the roof, and a great number of trams had to be filled before the face could be reached.

An examination of the face showed that the bottom of one of the shot-holes had reached to within a few inches of a seam of coal which was almost vertical and some 3 feet thick. The outburst of gas and coal dust had taken place through a circular opening some 18 inches in diameter which had been formed in the remaining few inches of clift apparently left by the shots. A large cavity from which the pulverised coal had come could be seen between the top and bottom of the seam.

Several members have referred to electric safety lamps being a possible source of danger under similar circumstances, and in this connection I should like to say that had these lamps been used exclusively at the time of the outburst I have attempted to describe, I think it extremely unlikely that any of those present would have escaped suffocation. Owing to the gas which was released being singularly free from odour, and the noise caused by the outburst being so similar to that made by a heavy fall over timber, it is highly probable that nothing but the extinguishing of a number of oil safety lamps would have been sufficient to warn those present of their danger in time to enable them to reach fresh air.

At the same time it should be remembered that the presence of even one electric lamp would have been of the greatest assistance in enabling the number of men present to reach safety, and the point raised by Mr. Greenland Davies, as to the difficulty of men having to find their way out in the dark under such circumstances, is undoubtedly of great importance.

I should add that the ground through which the drifts were being driven was virgin, and although the same, or other, seams had been intersected in similarly contorted ground no

outburst, as far as I am aware, took place except on the occasion described. **Mr. B. F. Kerridge.**

I regret that sufficient data is not now available to enable anyone to give such a comprehensive description of this occurrence as that supplied by Mr. Roblings of the Ponthenry outburst, but I trust that the foregoing notes will prove of sufficient interest to justify their being contributed to the discussion of this very interesting subject.

Professor HENRY BRIGGS (Edinburgh) wrote: **Professor Henry Briggs.**

Several interesting questions arise out of Mr. Roblings' excellent paper, but foremost among them stands those relating to the mechanism of these outbursts. How is the gas held in the soft coal, and does the peculiar physical nature of the coal play any part in the retention of gas under pressure? In the hope of being able to throw light on the subject I asked Mr. Roblings to be so kind as to let me have a sample of the material from the outburst and one of the normal anthracite of the seam. I have to thank him for the readiness with which he complied with the request. As none of the soft coal from the original outburst was available, he sent me some from a second outburst which took place in November.

I have subjected the substance to a number of tests, and these—for the work is not yet completed—are giving illuminating results. When the experiments are finished I hope to make them the subject of a separate paper; yet it would ill reward Mr. Roblings for his kindness if I did not make a brief communication to this discussion, even though, in so doing, I run the risk of putting forward figures which may eventually be found to need modification.

The first point relates to the composition of the outburst material. According to Mr. Roblings, who, in a letter to me quotes analyses by Mr. C. A. Seyler, the soft coal from the

Professor Henry Briggs.

original burst differed but little in ultimate composition from that of the unaltered anthracite, the only marked variation being, in fact, that of sulphur, whose proportion in the soft coal was ascertained to be over twice the proportion in the strong coal. So far as mineral matter is concerned, Mr. Seyler found the soft coal to contain less than the unaffected anthracite. My own results do not agree with the latter determination, the ash of the soft substance from the second burst (9·3 per cent.) being greatly more than that of the strong coal (2·0 per cent.). Moreover the ash of the former differs in character and colour from that of the latter to such an extent that they might have come from coals of totally different seams. It will interest me greatly to read the views which the members may express in explanation of the change which has taken place in the amount and nature of the ash of the coal. That the additional mineral matter was carried into the soft coal in aqueous solution appears at first sight likely, but the theory does not readily square with the absence of all signs of cementing material. Though not strictly *a propos* of Mr. Roblings' paper, it may here be mentioned that Professor P. F. Kendall, in a paper on ' The Anthracite Problem ' read in 1914 before the Leeds Geological Association, alluded to the fact that the ash of coal generally diminishes as the anthracitic character becomes more pronounced, and expressed the opinion that the ash found in coal was to a large degree not the original ash at all. He came to the conclusion that the diminution in the ash-percentage was due to the removal of much of the original mineral constituents, and the higher ash of bituminous coal to the introduction of new ones.

The inquiry into the chemical characteristics of the outburst coal is being continued.

I tried to restore as nearly as possible the *status in situ* of the soft coal by filling it into a steel cylinder and allowing Porth

Professor Henry Briggs.

firedamp to enter until equilibrium was reached at 120 lb. per square inch. The gas was then allowed slowly to escape and the pressure in the cylinder was observed as each litre of gas was emitted. The interstitial space existing between the particles was evaluated and the necessary allowances made to correct for the fact that, in its undisturbed state in the seam, the interstitial space would probably be *nil*. Further tests were made at the temperature of liquid air ($-190°$ C.), at which temperature an adsorptive is enormously more active than under ordinary conditions. The results clearly indicate that the soft coal can absorb large volumes of gas, and, indeed, that, at the pressure named, 1 cubic foot of the dry coal will hold in a state available for rapid discharge about 88 per cent. of the volume of firedamp that is held by 1 cubic foot of purely gaseous space subjected to the same pressure. Mr. Roblings mentions that, in the first burst, 280 tons of soft coal were flung out or otherwise disturbed. At the specific gravity of the sample sent to me this is equivalent to a volume of approximately 6670 cubic feet. An open space of this size containing gas at 120 lb. per square inch would discharge about 54,450 cubic feet if it were broken into ; therefore the volume of gas discharged by the coal was about 48,000 cubic feet. At the time of writing I have no facts as to the actual pressure of gas existing in the solid coal in the seam in question. My estimate of 120 lb. per square inch is possibly on the low side, and I should value information on this matter. At any rate, the quantity of gas suddenly emitted was so large that there can be no difficulty in understanding the great development of force to which Mr. Roblings alludes. If the gas were rich in CO_2 a still greater volume would be adsorbed.

Mr. Thomas J. Morgan.

Mr. THOMAS J. MORGAN, Penygroes, Llanelly, wrote :

Whilst Mr. Roblings' paper on the outburst of gas and dust at Ponthenry Colliery is under discussion it may interest

Mr. Thomas J. Morgan.

members to know of the circumstances attending a similar outburst of gas which occurred at Emlyn Colliery some years ago. The Emlyn is an anthracite colliery situated on the division line between the Amman and Gwendraeth Valleys in Carmarthenshire. The outburst in this instance occurred in the Lower Triquart seam, a small seam of 2 feet 3 inches to 2 feet 5 inches normal thickness which overlies the Lower Pumpquart seam by about 11 yards. It took place near the face of the main slant in this seam, and in a disturbed area at a depth of 1100 feet below the surface. It was an outburst of gas alone. Coal dust was entirely absent. In a few minutes after the outburst the slant was filled by firedamp upwards for a distance of 320 yards against an intake air current of 4500 cubic feet per minute, which was circulating at the time. Firedamp was not detected at the face of the slant preceding the outburst, neither was there any squeeze noticeable, nor any other indication of approaching trouble.

The outburst occurred during the afternoon shift when only two persons were engaged at the face of a level 300 yards distant from the slant on the return side. It would be well to explain the manner in which these persons escaped with their lives and without injury. They were not disturbed in any way by the report of the outburst, which was heard very distinctly by a few colliers at work in the Lower Pumpquart seam situated at a distance of 600 yards from the seat of the outbreak. These men were under the impression that an explosion had occurred and made a hasty retreat from the mine.

The hitcher, who was standing on the Triquart slant on the outlying side of the seat of the outburst, heard a heavy report and felt a momentary reversal of the air current, made his way quickly towards the bottom of the slant, and when within 200 yards or so of the face the light of his lamp was extinguished by firedamp. He then retreated up over the slant, and when

Mr. Thomas J. Morgan.

opposite the entrance of the level where the two colliers were at work he realised that the firedamp was being forced towards these men. He had the presence of mind to open the separation doors at the mouth of the level, thereby making a short circuit for the ventilation, and enabling a current of fresh air to go direct to the face where the two colliers were at work. This prompt act on the part of the hitcher very probably saved their lives. The hitcher then went up over the slant for assistance and returned a few minutes later to find that the slant was filled by firedamp for a distance of 45 yards above the entrance to the level where the men were at work. The firedamp remained stationary at that point for several hours, and the first impression given by this immovable body of gas was that the ventilation of the district had been completely stopped. However, on making an inspection of the return, a much larger volume of air than usual was found to be circulating and was heavily charged with firedamp. This increased volume of air was due to the short circuiting through opening of the separation doors and also to the cutting off at the same time the resistance in the form of air pipes near the face of the slant. Whilst steps were being taken to increase the volume of air in the seam to bring about the rescue of the two colliers engaged at the face of the level, these men to our surprise made their appearance out of the darkness. When questioned as to their experience they stated that they were taking their food when the light of the two oil lamps went out suddenly and simultaneously. They realised that they were in danger and commenced to make their way outwards at once by creeping along the floor with their faces touching the rails. If they raised their heads only an inch or two they experienced a choking sensation. It took them forty minutes to travel 300 yards. This goes to prove that a thin layer of respirable air circulated under the body of the firedamp for that distance at

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least. When the gas was cleared away next day to enable an inspection to be made at the face of the slant the road was found closed by a fall of coal and rubbish in the Triquart seam. It should be explained that the last 90 yards of the slant had been driven in hard ground above the seam, and that near the face the seam rose vertically. The slant passed through the seam into the rock again for a distance of 12 yards. The quantity of coal and rubbish displaced could not even be estimated. After 65 tons were filled away without making an impression, it was decided to make a drivage through the fall, which proved an easy matter, as the seam lay in a vertical position. It should be stated that the seam at this point was of excessive thickness and the coal of inferior quality and friable. A similar outburst of gas never occurred before or since at this colliery.

Several precautions have been recommended with a view of avoiding or minimising the effect of these outbursts, i.e. to maintain a straight working face and avoid narrow drivages, and to maintain advance bore-holes in the face when there are indications of trouble. The drivage at Emlyn was in hard ground and no indication of the trouble was given, not even fire-damp given off in such quantity as to be detected in a safety lamp, therefore the precautions just mentioned were not applicable.

I have read Mr. Roblings' paper with great interest, and shall be further interested to know of the manner by which such a large number of men made their escape, seeing that their lights were extinguished and that the gas filled the slant for such a long distance. It is evident that more than one ventilating district was affected ; if so, what was the effect on the other ventilating districts ?

The President.

The President said, having heard of occurrences at a North of England colliery similar to that at Ponthenry, he wrote to Mr. Lishman, the agent, asking for particulars.

Mr. T. A. Lishman wrote : Mr. T. A. Lishman.

'I trust the following particulars of outbursts of coal at Easington Colliery may be of some assistance to you. The first report we had of an outburst was in April 1914, in our Main Winning going west, about 1100 yards from the shaft. The place had gone through two rise hitches, and had just got through a dip hitch of 30 inches when the outburst occurred, the hewer being knocked over the hitch and covered with the fine coal. He was dead when we got him out, apparently suffocated. About seven tons of coal were blown out on this occasion. A second blower occurred in the return place adjoining, shortly afterwards.

'We had a large outburst in May 1916 (in No. 3 Headways), when upwards of 60 tons of coal were blown out, and the man and tub were both blown to the end of the place, 36 feet back. The man's thigh was broken, and the tub was turned completely round. The coal was absolutely "duff" and had been blown out the complete width of the place.

'We then commenced to bore in all these headways, keeping the boreholes 10 yards in advance of the face. In June 1916 the men complained of difficulties in boring, and one of our master shifters went in specially to see that a hole was bored in No. 5 Headways. After putting on 28 feet, the pressure was so great that the stand of the machine commenced to bend. On releasing the machine the whole of the rods were blown out of the hole to a distance of 30 feet, and 32 tons of coal were blown out of the face. The machine in use was a Burnside Boring Machine with water circulation.

'In each of these cases there did not appear to be any large quantity of gas given off, as we were able to get into the face after a very short interval.

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'The effect of boring these places was very marked, the output per man being reduced from an average of 7 tons per man to $1\frac{1}{2}$ tons, owing to the coal being "winded."

'All these outbursts occurred whilst we were approaching a small hitch.

'I have reason to believe there were several small outbursts which were not reported, as the men obtained the advantage of filling the loose coal.

'We use electric lamps, but since these blowers occurred we provide an oil safety lamp for each headway in addition to the electric lamp.

'I enclose a tracing showing places where these outbursts occurred.'

Mr. J. McLeod Carey.

Mr. J. McLeod Carey, H.M.I.M., asked the name of the seam to which Mr. Lishman referred.

The President.

The President: The Hutton seam, 5 feet or 5 feet 2 inches thick, with a shale roof.

Sir Aubrey Strahan.

Sir Aubrey Strahan (late Director of Geological Survey) wrote:

I may say that I have read Mr. Roblings' paper with much interest. I should suppose that the phenomena described were due primarily to the existence of masses of friable coal charged with gas under pressure, and isolated from the areas in which the coal was normally developed by gas-tight barriers of rock or shale. Mining operations appear to have weakened the rock barrier until it gave way under some slight disturbance caused by a workman. The first eruption of gas and coal that ensued would tend to reduce the resistance offered to the escape of any further accumulations of gas farther back. Eventually the whole mass or masses of gas-charged coal would be discharged, much in the same manner as water and steam are discharged from a geyser. The reference made in the paper to a series of reports increasing in intensity and

accompanied by a sound resembling the whistling of a gale suggests some such explanation. Sir Aubrey Strahan.

Mr. George Roblings, replying on the discussion, said the investigation into the causes of these outbursts certainly involved the calling in of many branches of science to their aid, but where the coal had also undergone a change, calls on further branches had to be made, with the result that such investigation became exceedingly complex. Several points had arisen during the discussion, and amongst others he was indebted to Mr. D. F. Davies for reminding him of Professor Fearnsides' theory of the formation of wash outs. While there was a possibility of utilising this theory of local and horizontal earth movements partly to explain the irregularity in the coal seam, yet there was at Ponthenry no evidence of any conditions similar to those described by Professor Fearnsides, in that in the first place there was an entire absence of broken ground or the intrusion into the horizon of the seam rocks from higher horizons, the irregularity here being entirely in the floor and the lower coal, the top coal resting apparently conformable to the floor in the centre of the disturbed area, but yet obviously quite unconformable. The principal movement had been in the floor, the western edge of the strip being limited by the step seen in Fig. 3 of the paper, which showed unmistakable signs of vertical movement by the presence of slickensides, there being no sign of it in the top coal. It might be therefore assumed that this movement took place before the deposition of the top coal as referred to in the paper, but it would be difficult to account for the difference in the state of the bottom coal on both sides of the step. They might, however, assume a combined local vertical and horizontal movement, due possibly to a cause similar to that which Professor Fearnsides ascribed to the so-called wash outs, as described by the late Professor Sorby in the 'Q. J., Mr. George Roblings.

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Geological Society,' 1908, which, stated shortly, was that 'the water originally contained in the slimes and muds from which the shales were formed, being pressed out by the superincumbent strata, reduced the volume and caused local movements in the strata on a relatively small scale, some horizontal and some vertical.' The latter would result in small steps involving possibly only a few beds. One of such steps was undoubtedly present in this case, with the floor having sunk.

There would appear to have been a heave in the floor about 40 yards away from the step where the bottom coal was nipped out completely. The bending of the strata in this form appeared quite natural when consideration was given to the action of bending. Notice the bending of iron on an anvil, and they would see that the portion over the anvil rose, which was due to the resistance of the material to bending. It might be urged that the rocks were more brittle than iron, and would be more likely to break, but it should be remembered that the term 'flexibility' was more or less relative, and those who had trouble with creep or puckings in mines had good reason to know that the rocks sometimes behaved as if they were the most flexible of matter or even viscid in nature. It was thus quite reasonable to expect this ridge in the floor, if they accepted that the floor sank at the time of fracture. This would tend to nip out the lower coal, but he did not think that the coal could have been pushed to the hollows without some amount of horizontal movement.

If the vertical and horizontal movements were simultaneous, then the coal, being the weakest part of the strata would be rolled up and pushed into the vacant spaces due to the sinking of the floor, and result in intense crushing.

The movement was probably a slow one, and it was possible that during this time there were hollows, and the

coal being rolled and crushed fine, the methane which would rapidly collect in the hollows would be absorbed into the coal. The tests made upon this small coal by Dr. Briggs explained this property. **Mr. George Roblings.**

The ability of small coals to absorb gases in greater quantities and faster than large coal had been repeatedly proved by tests. Mr. Ivon Graham stated at the Fed. Inst. Mining Engineers that the coal crushed to pass through a 90-mesh sieve absorbed relatively 50 per cent. more methane than large coal from which the sample of small was taken.

Dr. Briggs stated that his analysis showed that the difference in the percentage of ash in the normal and soft coals was far greater than that found by Mr. Seyler. It was possible for both to be correct, inasmuch as there was no reason to believe that the composition was uniform throughout, particularly when they considered the movements that must have taken place, but both gentlemen were agreed as to the difference in the character of the ash, and while he had not been told what was the nature of the ash, nor the mineral matter which produces it, he might be permitted to suggest that the thin bed of soft rashing normally existent between the two coals was in the rolling process mixed up with the crushed coal. The soft coal showed distinct traces of intense crushing in that a cleavage was so well developed that it was apparent even in the finest particles. Some of the dust when examined microscopically exhibited this structure, hence explaining why the coal was so friable, since the particles naturally part at these faces.

Dr. Lessing, in the Institute of Mining Engineers, in a paper on Distribution of Ash in Coal, stated that friability was in some way connected with fusain (the mother of coal). This might hold true when they considered how the coals broke up, when this material was minutely interstratified with the other ingredients of the coal; but the explanation did not hold in the

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case under notice, the quantity of fusain being very small. A minute examination of the coal 'in situ' showed intense crumpling and contortions, together with slickensides in a direction pointing to a horizontal movement from the north-east; the coal showing the latter character was highly polished, grooved, and appeared solid, but fell to dust immediately a piece was removed. There were also patches between the top and bottom coals of a slimy, flexible, leather-like layer of clod about $\frac{3}{8}$ in. thick, with a highly polished surface, indicating the line of demarcation expected in a horizontal movement.

It might be urged against the theory of horizontal movements that if they had taken place over a small area it should, owing to the solidity of the beds, have been extended over adjacent areas where there was no definite evidence of such movements. At the same time it might be put forward that owing to the clean parting between the coal and roof a considerable movement could have taken place, thereby polishing two adjoining surfaces.

Mr. Davies referred to a spot known to him where there was a space of 200 yards in this same seam where the roof and floor were perfectly comformable, and he (Mr. Roblings) might add there was to the north of this spot an area of coal of excellent quality, increasing in thickness from zero to 11 feet and thinning out again.

A section would best illustrate it showing layers of coal of the normal thickness of the seam lying one on another at about 45° to the horizontal, and the clod usually overlying the coal tailing down between these layers. There was also a thin tough, leather-like bed $\frac{1}{2}$ in. thick between the coal and the roof, something similar to the leather bed used by Professor Fearnsides as one of the signs of horizontal movement.

He had also noticed in some cases the roof affected to such an extent that the clod and shale forming the roof had

been curled up, so that their ends had rested vertically on the coal. Mr. George Roblings.

To account for the reason why the coal had been crushed in some places and not in others, there must be introduced other factors which were at present somewhat obscure. To estimate the age of this disturbance was still more difficult, notwithstanding the fact that it appeared to be branching from a member of the N.N.W. system of faults; the connection was, in his opinion, more apparent than real, since he could not connect the earth movement causing this disturbance with the Charnian movement at any of its periods of activity. These disturbed areas were found in an irregular manner.

He had to thank Mr. Davies for calling his attention to an error in the nomenclature of the seam. He should have stated the Lower Pumpquart of the Mynydd Mawr District, and not the Ammanford District.

With reference to the points raised by Mr. Ashworth, he had to state that patches of soft coal had been met with in which no trouble from methane was experienced. It might, however, be stated that sufficient notice had not been taken of any circumstances which by their difference or similarity would assist in forming a theory as to why there would be more gas in one patch than another. The difference or similarity in the compositions, as shown by the analysis, could not convey an adequate idea of the difference between the two coals, owing to the fact, now well proved, that coal was of such a complex character. It is possible to find two bodies of similar composition in so far as the proportions of the elements were concerned, yet possessing different properties, such as the two sugars, dextrose and levulose, and hence resort should be made to the microscope. Some of the fine coal was examined, but it was only possible to find occasional particles sufficiently thin to be translucent. One such particle

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was seen to be fibrous in character and quite unaffected between crossed Niclos during complete rotation. It was not, however, possible to make a complete examination, since all the particles were quite loose on the slide.

It was convenient at this point to refer to the matter of heating. It had been suggested that it was due to oxidation. Exhaustive experiments had been carried out at the Doncaster Laboratory by Dr. Haldane and his able assistants, Messrs. Winmill and Ivon Graham, on the 'Absorption of Oxygen by Coals' of various kinds, some of which were from the Big and Peacock veins, and in the case of the Big Vein the following would be of interest, taken from the paper by Mr. Winmill on the 'Absorption of Oxygen by Coal' before the Fed. Inst. of Mining Engineers, in 1916.

Sample.	At 60° C. through 60-mesh sieve.	At 30° C. through 60-mesh sieve.	At 30° C. through 2 and over 10-mesh sieve.
After 2 hours	50	23	2·07
,, 4 ,,	18	15·2	1·72
,, 8 ,,	9·9	9·8	1·3
,, 24 ,,	3·2	3·4	0·8
,, 96 ,,	0·4	1·1	0·5
Total after 96 hours in c.cm.	450	381	75

Mr. Winmill stated that absorption by anthracite was high when compared with coals known to be favourable to spontaneous heat, but that at higher temperature anthracite slackened off in its absorptive power.

The anthracite appeared to have a definite capacity for oxygen, and though this capacity is satisfied more quickly as the temperature rises, the total absorption is unaltered. In these circumstances the coal could not possibly fire spon-

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taneously. Mr. Winmill stated that it was not a simple surface action, but that the oxygen in some manner penetrated the coal particles. Other factors being equal, coal dust was far more likely to originate combustion than lump coal.

'A small sample of (Barnsley) coal dust, which was placed on the laboratory table, and was supplied with sufficient oxygen, and at the same time was prevented from losing heat, burst into flame in twenty-four hours.'

Here they had definite proof of the effect of oxidation, and it certainly supported the view that the heating was due to oxidation, but it was difficult to conceive such an action taking place when the percentage of oxygen was obviously very low—in fact it was difficult to imagine any oxygen at all being present with such an outrush of methane. However, they might be assisted by the further experiments described by Mr. Winmill as to the effect of varying percentages of oxygen, in which it was shown that when the percentage of oxygen fell as low as 8 the absorption was still 65 per cent. of that in normal air. Personally he (Mr. Roblings) did not think that the pyrites played a very important part in causing the heat.

Mr. Ashworth suggested that friction had had something to do in assisting the heat. He (the speaker) was not disposed to rule it out, since the position where the greatest heat was apparent was in the coal which was expected to have been blown out first, and all the coal blown out subsequently would pass over it, probably rubbing it on its journey, raising the temperature and materially accelerating the absorptive capabilities of the coal heap.

Mr. Ashworth also suggested the possibility of the generation of static electricity. He agreed with him, since it was well known that when eruption of ashes took place out of volcanoes, flashes of lightning were usual accompaniments, undoubtedly produced by the friction of particles against each other. An interesting paper dealing with this question was read in 1914

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before the Royal Society by Mr. W. A. Douglas Rudge, M.A., in which an account was given of a series of experiments on different dusts. A portion of the summary drawn up by him was that the raising of a cloud of dust was accompanied by the production of large charges of electricity. Some of the dust particles had positive charges and others negative. Either one set of charged particles settled rapidly, leaving the other set in the air, or else a charge was given to the air itself. The experiments did not show which of these views was correct. The charge was retained by the air for some considerable time.

'The sign of the charge remaining in the air depends upon the nature of the material used; he states that organic dusts, including coal dust, give a positive charge. . . . An unweighable amount of dust can produce an easily measurable charge.'

These conclusions were arrived at after an exhaustive series of tests, and it might be of interest to give an extract referring to one experiment with cornflour dust: 4 centigrammes of cornflour, blown into a room 250 cubic metres, charged the air to such an extent that a radium-coated collector rapidly indicated a potential of 200 volts, and the charge persisted for some time.

These experiments lead one to form the opinion that there must have been a considerable charge of static electricity, but whether it had anything to do in assisting the heating of the heap was not sufficiently clear. One should hesitate in the absence of direct proof to the contrary to say that it did not have something to do with it. So one would be led to expect some startling phenomena had it been possible to test for it, and these might play an important part in rendering coal dusts easier of ignition when in a state of suspension. There was also the possibility of some amount of heat being generated by the expenditure of energy which must have been considerable by being blown out from its place.

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He did not agree with Dr. Briggs that the whole of the gas was blown out in one outburst, but thought that it continued for an appreciable time. This was supported by the appearance of the heap of small coal, which was similar to a wind-swept sand dune. He was also of opinion that Dr. Briggs's estimate of the amount of gas was short of the actual, as 10 per cent. of the volume of all the roadways would exceed this figure, and he did not think there was less than an average of 10 per cent. of firedamp in the whole of them, and this even persisted for some time.

A good deal had been said on the question of lamps, and he was bound to agree with the ex-President and those other gentlemen who stood for both electric and oil safety lamps, but he did not think that an electric lamp at the bottom of the slant would have saved the one life lost, because the five men who worked at the bottom were undoubtedly rendered unconscious by the gas and dust, and remained so for some time. They subsequently recovered, probably from the fact that they fell into the middle of the road, and into a stream of water, and the possibility should also be admitted of the effect of the exhaust from a small compressed air pump which continued working within 2 or 3 yards of them, while the man who lost his life had been the first of the men to get away and was subsequently found kneeling against some timbers about 50 yards above this pump, with his nostrils and mouth full of fine dust, to which, coupled with the facts that there was a deficiency of oxygen and that he was somewhat asthmatic, he (Mr. Roblings) attributed his death, and he had no doubt but that he was dead before the other men had recovered, which was only a short time prior to his being reached by a search party. No amount of light would have prevented this.

Electric lamps would assist the men in getting out, but they would not prevent such a case as came under his notice

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on that day. One of the colliers coming out on hands and knees from the lower heading on the east side (to be seen on the plan, Fig. 7 of the paper), when opposite the airway felt a strong current coming upwards, and under the erroneous impression that he was getting fresh air breathed it deep and well, but immediately feeling the effects managed under great difficulty to crawl away. A system had been adopted at the colliery by which there was an electric lamp in nearly every winning place and a few scattered about the workings. He agreed with the ex-President and Mr. D. F. Davies that it would be highly dangerous to remove oil safety lamps entirely from the mine unless a really efficient gas detector giving audible warning was designed for attachment to the electric lamps, and he would, in its absence, consider that the proportion of oil safety lamps stated by Mr. Davies as the very lowest consistent with safety.

In reply to Sir Leonard Llewelyn, this ground could not be said to be virgin, inasmuch as the seams above (one 80 yards and the other 110 yards) had both been worked years ago.

With regard to the ex-President's remarks as to the small spurts or blowers, prior to the large outburst, these were taken by the colliers to be the working of the coal, and they often pounded the coal to bring work into it, a procedure which he was now given to understand was carried out with some effect when this outburst occurred. He (the ex-President) had made a slight error in saying that the coal was quite hard up to the moment the outburst took place. Reference to Fig. 3 would make it clear, but it would have been quite true had they approached it from the opposite direction.

They had recently experienced trouble in the main slant in passing through this soft coal. One outburst occurred from the right-hand side when the coal was only 2 feet in thickness,

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and quite unexpectedly, which filled the slant for 10 yards, forced a full tram of coal for about 3 yards up the slant and tumbled it against the side, knocking out three pairs of timber. The collier when picking at the parting between the top and bottom coal noticed the coal to his right gradually moving, and he immediately got away. The gas followed him for 200 yards up the slant, but immediately slackened off. Work was carried out on the afternoon shift.

Since then a series of boreholes varying from six to thirteen were kept in advance to the extent of about 8 or 9 feet. Varying quantities of gas were being released. In some cases, particularly at about 2 feet from the floor, when the coal was from 5 to 8 feet thick, it was released at such a rate that the dust was carried out of the hole for several feet; and although it certainly acted as a blowing safety valve in releasing the pressure it did not remove the necessity of exercising great caution in working the coal, as the gas was undoubtedly occluded throughout the whole of this portion of the seam, at such a pressure that when the coal was rapidly worked away, the resistance to bursting was so suddenly removed that the escape would continue for some time and extend far into the seam. He had noticed cracks in the coal from which gas and dust had been released for as much as 20 yards.

The gas collected from the boreholes was analysed by Mr. Clarence Seyler and found to contain as much as 98 per cent. methane.

The President.

The PRESIDENT said they were very much indebted to Mr. Roblings for his interesting paper, and for the addition he had just made to it. The subject was important, inasmuch as it brought before them circumstances of a mining phenomenon very difficult to meet and explain, these occurrences being unexpected. Mr. Roblings had adopted measures that were probably the best calculated to avoid these outbursts

The President. —i.e. by keeping a series of boreholes in advance of the headings. He believed that at the Hampstead Colliery, Warwickshire, where something of the same sort had been experienced, a similar course had been pursued. He had pleasure in asking the meeting to accord to Mr. Roblings a hearty vote of thanks. (Applause.)

The discussion was closed.

On the Use of the Cement Gun for Underground Work in Collieries and for Housing Construction.

By A. E. Parker.

(Paper, *vide* Proceedings, Vol. XXXVI., No. 1, p. 439; Discussion, p. 447.)

Replying on previous discussion of his paper,

Mr. A. E. Parker. Mr. A. E. Parker said he was pleased to hear the ex-President, Mr. Dyer Lewis, express the opinion that there was evidently a future for the 'Cement Gun,' and suggested that if gunite proved effective in affording protection against weathering of underground roadways it would render a good service. Work actually done with the machine and gunite showed its efficacy in these respects. With regard to stopping air leakage past gobbing, one of the 'Cement Gun' methods successfully used in the United States consists in wedging wooden props having a section of 2 inches by 4 inches between the roof and the floor of the road. These props are placed about 20 inches apart and tar felt and reinforcing mesh are stretched over them; subsequently gunite to a thickness of $\frac{3}{4}$-inch to 1 inch is shot over the reinforcing mesh against the tar felt, so that the gunite layer connects closely to the roof and floor of the road. Thus a perfectly airtight wall is formed, reducing air leakage to a minimum.

Mr. W. D. Wight had expressed doubt whether an inch

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or half an inch of gunite would support the roof in live ground. Mr. Wight was quite right—this was not suggested or claimed for it. The application of gunite only prevents slacking due to 'weathering' by keeping the air out of the road. Gunite protects roofs or walls from cracking caused either by the weight of the over-burden or by the difference in temperatures, although with regard to the latter point it should be emphasised that gunite itself is fireproof and is proved by extensive tests to be capable of withstanding very high temperatures.

Mr. O'Connor had spoken of the use of the 'Cement Gun' in the United States, and pointed out that the changes of temperature in American mines were very much greater than those to which they were accustomed in this country. Mr. O'Connor was accompanied in his visits to American mines by Mr. George S. Rice, of the American Bureau of Mines, who has had a good deal to do with the use of the 'Cement Gun' in American mines, where the machine was now being used to great advantage. Equally good results can be expected in mines in the United Kingdom, where temperature conditions are more uniform.

Mr. Evans, of the Albion Colliery, expressed a fear, with reference to the necessity, before applying gunite, of removing loose material from the roof and sides, that under the conditions which he had to deal with they would have to go on removing loose material for ever. It should be emphasised that it is necessary for all loose shale to be removed entirely if the application of gunite is to be successful. Mr. Evans suggested coating arches with gunite. This is a good suggestion, and in fact guniting arches in mine roads has proved itself most satisfactory.

While considering the principle of the machine to be correct, Mr. Mort thought it required a bigger mesh than $\frac{1}{4}$ inch. At present that was the maximum size of the material which

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could be used in the machine, but those who were responsible for the machine were seeing if it were possible to increase the mesh. So far, however, they found that the best results were obtained with material not exceeding $\frac{1}{4}$ inch. In reference to Mr. Mort's concluding remarks gunite had been shot as high as 200 feet with a pressure of not more than 50 to 60 lb., and a normal pressure of 35 to 45 lb. is perfectly sufficient to reach to the top of any scaffolding set up underground. It may be not out of place to point out that the scaffolding necessary for gunite work has to be only sufficiently strong to carry the weight of the workmen, there being no necessity of its carrying the weight of the coating materials, which are automatically conveyed through the 'Cement Gun' hose. Of course this is of considerable advantage.

Mr. Dyer Lewis had put a question as to the life of the 'Cement Gun,' observing that at the bottom of the machine there seemed to be a considerable amount of friction where the sand is ground up. The sand-cement mixture is not ground at the bottom of the machine, but is fed under air pressure to the outlet valve, the friction being reduced to a minimum by having the feed-wheel machined carefully on all its surfaces coming into contact with the sand and cement. In fact, the friction in the 'Cement Gun' is exactly the same as in any ordinary mechanism.

Since the particulars were given in October last, the 'Cement Gun' had been installed in many collieries in South Wales and Monmouthshire, in England and in Scotland. The Powell Duffryn Company had very kindly given particulars in October last of work done by the machine, and in January last Mr. J. A. Price, the agent of the Powell Duffryn Company in the Aberdare Valley, said that the gunite which was put on at Cwmneol Colliery and Lower Duffryn Colliery was still holding good, and showed no signs of giving way. He also expressed

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the opinion that there is no doubt that gunite prevents weathering of sides and roof in dead-weight or set ground.

On March 15th, Mr. Price stated that the roof and sides which had been treated were still holding well. When he (Mr. Parker) said that such companies as the Powell Duffryn Company, the Tredegar Iron and Coal Company, and the Lewis Merthyr Company, among other firms, were using this machine and up to date had expressed themselves satisfied with it, he thought it would be conceded that it was receiving the favourable consideration of some of the best companies in the South Wales coalfield. It was also being used with very satisfactory results in railway tunnel work, and gunite was being applied to a tunnel near London having a length of about 5000 feet. He (Mr. Parker) would be glad to furnish particulars of this work to anyone interested.

The President.

In moving a vote of thanks to Mr. Parker, the PRESIDENT said they must all agree that there was a future for the 'Cement Gun' in certain aspects of mining, especially, he thought, where no movement of the strata was going on that was likely to crack the gunite.

Notes on the Imperial Tie Tamper.

BY ERNEST BREFFIT.

(PAPER, *vide* PROCEEDINGS, VOL. XXXVI., No. 2, p. 457.)

On resuming consideration of this paper,

Mr. Breffit.

Mr. BREFFIT, in answer to a question by the President, said the Imperial Tie Tamper had not been used by the railway companies of this country, but was used a great deal in America. Major Mackintosh, who was present, had practical experience of the machine and would be glad to answer any questions.

The President. The PRESIDENT asked what was the minimum of railroad on which the Tie Tamper could be profitably employed.

Major Mackintosh. Major MACKINTOSH replied that there must be at least 50 miles of track that was being constantly repaired and renewed. A custom in America was to have one machine for each section of about six miles of double track. Extreme heat and cold which was experienced in America made it necessary to use this machine twice a year, but over here it would be sufficient to use it once a year for general lifting and refitting, so that one machine only would be necessary for double the American length of track.

The President. The PRESIDENT said that while in collieries they did not usually have as much as 50 miles of track to look after, he could well imagine that on English railways there was a big opening for this machine, which was evidently one of the many labour-saving devices which we so often got from the other side of the Atlantic. He proposed a vote of thanks to Mr. Breffit for having brought the subject before them.

Causes of Subsidences and the Best Safeguards for their Prevention.

By R. C. MORGAN.

(*Vide* PROCEEDINGS, VOL. XXXVII., NO. 1.)

Discussion was opened on this paper, to which had been awarded the Lewis First Prize, 1920.

Mr. H. W. Halbaum. Mr. H. W. HALBAUM expressed his pleasure at the fact of the First Lewis Prize going to a Student willing to tackle a really good, vulgar, purely mining question such as Subsidence; and not only willing to tackle it, but able to handle it in the efficient and interesting manner exemplified in this paper. Mr.

Mr. H. W. Halbaum.

Morgan has the rare gift of recognising just wherein lies the weakness of his case. It lies in the scarcity of his data. And he now innocently asks all and sundry for practical data. He will soon acquire the equally rare gift of waiting patiently until he gets them. But he will find that the most valuable data are those obtained by his own efforts. In my experience the man who seeks data of this sort from other men can make up his mind to spend forty years in the wilderness looking for figs on thistles and for grapes on fossilised trees.

This difficulty of obtaining complete data is due to quite natural and legitimate causes, which need not be specified here.

Mr. Morgan commences by stating that it will require a lot of study of results before any theory of the case can be formulated. I can hardly agree to that without qualification, especially as Mr. Morgan himself in his next sentence proceeds to state a theory which, in my opinion, is a very good theory indeed. I first stated that theory in connection with subsidences some sixteen years ago in a paper read to the North of England Institute. A year previously I had read a paper which took the theory and its soundness for granted, having no idea that anyone would object to my taking it as a postulate. For postulate it was, in my view, since it simply took for granted that subsidence in general would be governed by natural law irrespectively of the particular means by which the subsidence was produced. To my great surprise, many men refused to accept my postulates, with the result that I had to prepare a second paper—that now quoted by Mr. Morgan —to prove the postulates of the first. Those postulates are now accepted all over the world as a basal theory of mining subsidences. The funny part of the business is that they were never in doubt with respect to anything else. All men recognised that lateral pressure was responsible for our anticlines, our thrust-planes, and even for our common cleavage planes,

Mr. H. W. Halbaum.

but appeared to imagine that this force had retired from business, presumably in polite deference to public opinion, as soon as mining operations began. It evinces a step forward that we now know better. We always knew that the principle of the parallelogram of forces was true in a general sort of way: it is equally true in the particular case of mining subsidence and draw.

If the author of this excellent paper will go on as cautiously and cleverly as he has begun, there is not the slightest doubt but that he will find a few more of these unutilised theories lying about patiently waiting to enlighten him and all the rest of us about many things of which we remain at present in ignorance. But one must use them, when found, only where they apply in strict naturalness, and not where any application is strained, however plausible. I am sure Mr. Morgan will not mind my pointing out one instance in which I fear he has strained the cantilever idea. I quote from the bottom of page 56, where it is stated that: 'The depth of this beam, being the thickness of the absolute roof, would be greater than one-sixth of the length. . . .' This is one of those half-truths that so often lead the best of men astray. This absolute roof is a composite beam—a series of beams superposed one above another, and hardly two of them alike with respect to either size or resistance. A 3-inch fir plank with a 2-inch oak deal below and with a 4-inch slab of pine above is a very different sort of 'beam' from a 9-inch solid beam of wood, whether of fir, oak or pine. Where would the neutral surface be of such a composite beam? And if, say, the oak section of the 'beam' were the first to fracture, where would the neutral surface then appear? Oh yes; given the conditions, we can calculate the effect by a dozen theories, and sound theories too. But the difficulty is to fit the known theory with the unknown conditions, and to fit it like Paddy's home-made coat: just 'where

Mr. H. W. Halbaum.

it touches,' and nowhere else. It is so easy to try to fit it just where it won't touch, but we can never be sure that it does touch unless we can see the conditions as clearly as we see the theory itself.

One or two of the conditions are obvious: first, that the beam is composite; secondly, that, considered as a whole, it must possess a sort of theoretical neutral surface; thirdly, that at every successive fracture of section after section, the neutral surface changes its position; fourthly, that every shift of the neutral surface, whether in the whole beam or in a section of it, reverses the stresses in all layers through which the shift has occurred. It is these reversals of stress due to the shifting of the neutral surface that explain the heavy 'pounces' heard by Mr. Morgan, and the reverberating 'bowks' in thick rock roofs, as described in the paper referred to in Mr. Morgan's footnote on page 49. It would be interesting if Mr. Morgan would give us a supplementary paper dealing specially with this phenomenon of the shifting neutral surface in the composite beam of the absolute roof. In that we shall probably find a key to open many doors now shut to us.

The tables on pages 54 and 55 agree fairly well with the popular impression that the efficiency of packing is about 0·6, though the later results in District 3 seem a little discordant. I know personally of one case that showed an 'efficiency' as high as 0·98, and I have heard of another in the same neighbourhood showing an 'efficiency' so low that it could only be expressed as a minus quantity. In both these remarkable cases, the natural conditions and the working conditions were practically the same, although the result in each case was the antithesis of that in the other. The absolute roof in both cases consisted of the magnesian limestone above, separated from the coal measures below by a bed of running sand. The President and Mr. Bramwell doubtless recognise the locality,

Mr. H. W. Halbaum.

and possibly may have opinions differing from mine as to the explanation of the contradictory results.

The facts are that the surface was let down in the one case by 3 inches only. In the other case it was let down vertically through a greater distance than the whole thickness of coal extracted from the mine below. The whole of the strata dip gently to the east. The result in the first case, where there was practically no subsidence at all, may be explained as follows :

The absolute roof had three principal members, the magnesian limestone above, and coal measure shales and sandstones below, and the running sand between. As the lowest member subsided on the extraction of the coal below, I infer that the sands, under squeeze set up by the working of neighbouring collieries to the rise, flowed into the gradually enlarging cavern below the limestone and supported the limestone by hydraulic pressure. Only the coal measure strata ever stepped into place as the theoretical beam, the sands under pressure formed the load on the beam, and at the same time supported the limestone above by a natural continuously self-acting system of 'hydraulic stowing.' Hence there was practically no subsidence at the surface.

In the second case the depth of the subsidence at the surface was numerically greater than the thickness of the coal extracted below. It is obvious that the sand did not here assume the same office as in the last instance. The whole of the absolute roof broke up and subsided as in the usual experience of practice. Now, the magnesian limestone is traversed by many great fissures ; some of them can only be described as caverns interconnected the one with the other and containing large quantities of water. It is a common superstition in the north of England that it is traversed by large underground rivers. However that may be, it is certain that the formation

Mr. H. W. Halbaum.

contains inexhaustible supplies of water. In sinking Murton Colliery through it, the leathers for the pumps alone cost £11 per minute, equal to a cost of £40 per minute at the present time. When Mr. J. J. Prest sunk the Blackhall Colliery a few years ago, he kept the sinkers working in the pit bottom until he was pumping 15,000 gallons per minute, which is equal to about 100,000 tons of water per 24 hours. Still the feeders kept increasing, and the pits had to be put down in the end by the process of cementation.

It is easy to see that when this cavernous limestone breaks up and falls the mass of *debris* may very naturally be much more nearly solid than the original structure, just as the heap of bricks obtained from a demolished house may have much smaller dimensions as a heap than the building had as a house. In this way, the second case is explained even more easily than the first. But who could have predicted either of them beforehand? We have the theory all right: it is not theories we are looking for, but for some means by which we can ascertain the natural conditions of the composite beam, and also the general environment of the beam, the knots that disfigure it, the piers that support it, and the stresses to which it is likely to be subjected. Our theory is sound enough and wide enough to cover all cases—but the trouble is that so many of us know so much more about foreign geology than we do about the physical geography of our own country, and so much more about the differential calculus of natural law than we know about its elementary algebra. To quote Mr. Lloyd George, we rush to acquire 'startling and reliable information about the next world' before we have even glanced at the first principles which might enable us to understand our own. The cure for this state of affairs is not an extended study of abstract theory, but a vastly more earnest investigation of concrete conditions.

Mr. H. W. Halbaum.

The North of England Institute have done splendid service in this direction, so far as Durham and Northumberland are concerned. They have published, in four large volumes, records of all the borings and of all the shaft-strata in the two counties, with few exceptions, and the members of that Institute have thus set an example that might be followed elsewhere with advantage to all concerned. Some men might think that the giving away of all these valuable data was an injudicious giving away of the position to the enemy's spies. To some extent it is. On the other hand, it must be remembered that the 'enemy,' by taking a little trouble, can, in 'time of war,' force the position whenever he sets his mind on it. And there is also quite another side to the whole question. It is all very well to 'camouflage' your position in face of the enemy, but is it also wise to conceal it from the reinforcements which are flocking to your help? In the present state of the law, any man can demand access to the plans of your fortress provided he proclaims himself openly to be at war with you? Then why conceal the plans so effectively under other circumstances that even your own officers lose themselves on the premises?

If the South Wales Institute has not already got this stratigraphical information collected in handy form for the use of members, I hope they will consider the advisability of placing it at our disposal at an early date. At the present moment most of us know far more about what the Mississippi and the Amazon are doing in America, and about what the Nile is doing in Africa and the Ganges in Asia, than we know of the doings of the Taff and the Rhymney in South Wales. I was surprised a short while ago to find, on personal investigation, what some of your innocent-looking little rivers are doing, and I have not the slightest doubt but that some of our colliery owners have at one time or other had to pay smartly for the simple fact that there are such things as rivers in South

Wales. But the difference between the colliery owner and the river is that the man can write a cheque and the river can't. Mr. H. W. Halbaum.

The question is pre-eminently one of data, and hardly at all one of searching for a theory. The theories are ready to hand: they are proved theories: they are simple and not far-fetched: they are the great fundamental theories of physics, and physics is the same science in South Wales as elsewhere, the same in the air above and in the rocks below. It embraces mass, length, and time, and you have no other entity in South Wales physics than in physics elsewhere, and no domain of physics embraces more than the relationships between these three entities: mass, length, and time.

But the South Wales coalfield shows some singularly interesting specimens of these relationships; for one thing, the lateral force of the strata, so beautifully explained by Mr. Morgan, is practically a spent force over a large portion of your locality, and that is the great secret of the extraordinary and destructive squeeze that makes your mining operations in many cases much more difficult than in other parts of the land, and that is where the necessity of data asked for by Mr. Morgan arises. The most beautiful theory can do nothing without data; and Mr. Morgan has asked you to do your best to supply it. I have the greatest pleasure in adding my own petition to his.

Mr. W. O'Connor said he had not come prepared to discuss the details of the paper, but it occurred to him that it was a pity that Mr. Morgan's attention had not been devoted, in the first instance, to a field where there would be fewer varying conditions to be dealt with. It would be more easy to reason as to the effects of subsidence in the case of a virgin seam, where faults were few or non-existent and the whole of the ultimate roof undisturbed, before the working, which was the subject of the observations, took place. Mr. W. O'Connor.

Mr. W. O'Connor.

He ventured to think that data taken in such an area would assist in reasoning to the comparatively complex conditions of the area dealt with in the paper, where there was not only the irregularity introduced by the occurrence of several faults, but also that due to the fact that several thick seams had formerly been worked in the area in question.

Another direction in which information of great value could be obtained would be by observations on the effect of the given workings upon the surface levels, both as to amount and as to time.

Some few years ago some information on these subjects in another coalfield was published, which was of great assistance in enabling one to form some idea of what results might be expected to follow on mining operations in a seam at a considerable depth. He believed he was correct in saying that very little had been published in regard to this coalfield, and he had therefore great pleasure in complimenting the author of the paper on having given attention to the subject here.

The author referred to some portions of the overlying roof as being different from others, in that rivers had intersected that portion of the area and so isolated certain high-lying strata. He (Mr. O'Connor) would suggest that the author go still further, and make the investigation of this difference somewhat more geological in character. They knew where the Pennant Sandstones came in, and that they formed what was largely a very solid band of strata, and certainly added very materially to the strength of the upper roof where continuous, as compared with the portion of the area where the roof was principally coal measure shales, with isolated hills on each side composed of Pennant. It was fairly clear that in the latter case the loading would be much more irregular than where the Pennant extended over the whole surface.

As bearing on the question of surface subsidence, the speaker

remembered one striking occurrence. While investigating this subject in company with the Mine Cave Commission in the United States he visited a locality where a seam of coking coal about 7 feet thick was being worked in a modification of pillar working, about 8 yards being worked narrow, and the pillar of 8 yards being immediately withdrawn; the effect being practically that of removing the whole of the coal at one operation. The thickness of overlying strata would be from 60 to 80 yards. After inspecting underground, they proceeded to the surface overlying the then face of the workings, and found that the agricultural land presented a steep wave of some 20 yards or so in length, the total depression being about 5 feet, and so closely did this movement of depression follow the operations beneath, that the whole outline of the workings could be seen on the surface. As regards damage, the effect appeared to be quite temporary, the subsided portion showing no visible difference after the wave of depression had passed, either on the land or on the roadways traversing it. There were no buildings at the point in question, hence no estimate of what would result to such erections in the way of damage could be hazarded. Mr. W. O'Connor.

Principal GEORGE KNOX said when Mr. Morgan began to write this paper he impressed upon him the necessity of getting data in the neighbourhood in which he was employed. It was hardly Mr. Morgan's duty, as Mr. O'Connor suggested, to apply to other persons for information. What he wanted was first-hand information, and he was to be complimented upon that information and upon the way he had summarised it, and the deductions he had drawn from it. It was not easy to tabulate information concerning various coalfields and then arrive at a general conclusion upon the causes of subsidence resulting from mining work. When he (the Principal) was in Lancashire, he had an opportunity for seven or eight years Principal George Knox.

Principal George Knox.

of keeping a record of five seams. These seams were almost flat and were worked in a fairly flat country, one seam being worked in front of the other over a considerable area, and there was plenty of opportunity for making observations of a fairly accurate character. That part of the country was threaded with innumerable railways, along which, and particularly in the cuttings and railway-stations situated close together, splendid results were obtained of the line of fracture in advance of the face. It was remarkable that in the upper seam—about three hundred yards from the surface—the fracture kept almost constantly three hundred feet in advance of the workings, while the seam immediately behind increased somewhat beyond that, but not exact in proportion to the depth. If he remembered rightly the ratio was almost identical from the top seam to the bottom, although the distance in advance decreased in proportion to the depth. Unfortunately they were not allowed to publish the figures, the railway companies among others objecting. It was noticeable that the amount of packing had a considerable influence upon the actual rate of subsidence. The subsiding line of fracture in front of the workings was fairly regular, about three hundred feet in advance of the upper seam, and the fractures took place about every three feet as the working face advanced, and kept open until the coal face was immediately below the particular fracture, when it gradually began to close again as the workings advanced. The total amount of subsidence was something like twenty-eight per cent. of the total thickness of coal taken out. This he found in some parts of South Wales. In the Scottish coalfield, too, he had opportunities of examining this question for some years. There the conditions were very much different from those prevailing in Lancashire. Some of the workings in that part of the country with which he was associated were in the Mountain Limestone Series.

Alternating with the shales were thick bands of limestone. The seams were worked by long wall faces, and where the packing was done fairly regularly the gradual subsidence could be noticed for a considerable distance, and then would come an enormous settling down of the strata. A great deal depended upon the nature of the absolute roof as to what was going to happen when any part of the coal was taken out. One interesting case was the working of a seam about six feet in thickness between other seams which had been previously taken out, this seam not being considered of the same economic value as the ordinary run of seams in the coalfield. It was worked some time after the six-feet seam below, and it was discovered that this upper seam, which was known as the four-feet seam, was fractured and faulted in places for hundreds of yards—little slip-faults hading backwards—while immediately above the seam the fractures were visible hading forwards as if the change of the strain had taken place in these lower rocks after the working of the bottom seam had broken through the overlying strata. Principal George Knox.

In South Wales the problem was quite different from that of any other part of Great Britain, and if a number of students like Mr. Morgan would set about collecting information on this subject, and carefully tabulate the same, he felt sure the South Wales Institute of Engineers would give every assistance in its power in obtaining the geological information referred to by Mr. Halbaum. Efforts of that kind would certainly be of great help in solving this important problem.

The President said he considered Mr. Morgan's paper a very interesting one; and the author was to be congratulated upon the scientific manner in which he had considered the question of subsidence. He quite agreed with his suggestion of the cause of the greater crush experienced in the strata in South Wales compared with most other districts in the The President.

The President. United Kingdom, viz., that it was largely due to the uneven or unbalanced surface loads acting upon what the author described as the absolute roof acting as a beam. There were one or two points in the paper to which he might call attention: The author, on page 69, stated where the strata were soft the angle of pull was small, due to lack of cohesion among the rock particles and the consequent liability to fracture. This statement required some qualification. He (the President) had known cases where the strata were largely composed of hard sandstone where the angle of pull had been very small.

As a general rule he believed the author's statement to be correct, and where the strata was comprised of, say, a homogeneous sandstone, the angle of pull would be considerable, due to the fact that the hard roof tended to hang over the packs and subside gradually; the angle of draw in consequence extended far ahead over the solid coal; but in other cases, such as he had already referred to, where the sandstone, although very hard, contained a number of vertical joints, it would be found that the angle of pull was very small, and he had known cases where the position of buildings had been almost reached before the angle of draw had affected them.

In paragraph 7 upon the same page, theoretically it might be true that the effect of a fault by intercepting the prime face should make the angle of pull less; in practice it would, he thought, be often found that the pull or draw would be found to act along the hade of the fault without relation to the angle of pull which might have held good before the fault was struck.

He had known cases where buildings situated upon the surface line of a fault had shown damage, although considerably beyond the apparent line of draw of the workings.

On page 71 the author stated that in Germany, where hydraulic stowing had been carried out, the subsidence varied from 0·03 per cent. to 7·8 per cent. The first figure given appeared to be remarkably low. He had always understood that 2 per cent. was the minimum attained, and it would be interesting to know whether the author had any particulars of such a small subsidence. In a case with which he had had to deal, in which 14 feet thick of iron ore was extracted over an area of half an acre and hydraulically stowed with clean sand, the amount of subsidence averaged 3 to 4 per cent. The subsidence was measured by sinking iron pegs 2 feet long into the ground with their tops 3 inches below the surface and careful levels taken at intervals over five years. The President.

Another conclusion that seemed to be deducible was that if they set out to protect a particular building by hydraulic stowing they would have to start under the building itself, because the only damage likely to be done was just on the line of the draw as it opened out. He proposed to adjourn the discussion because it was an important subject upon which many members would probably like to express their views at a future meeting.

The discussion was adjourned.

Powdered Fuel.

By Robert James, Wh.Sc.

(*Vide* Proceedings, Vol. XXXVII., No. 1.)

Discussion was opened on the above paper.

Mr. W. A. Chamen said the subject of powdered fuel was receiving greater attention than had been hitherto given to it. The author said something about being able to burn Mr. W. A. Chamen.

Mr. W. A. Chamen.

powdered fuel containing as much as forty per cent. of incombustible material. While they had been going up by leaps and bounds in the matter of percentage of dirt in the coal, they had not yet reached forty per cent. of incombustible—at any rate, not as an average—(laughter)—although they occasionally got a truck-load of stuff that put out the fires altogether. What fuel consumers would like to know was whether this supply of extremely dirty coal was to continue, or whether things would improve in this respect when certain difficulties of which we all knew were adjusted. Had they to continue to be supplied with coal containing from twenty to thirty per cent., and sometimes more, of incombustible material? It was true that they were just now getting a larger proportion of previously washed coal. Was this increased quantity of available washed coal likely to fall off when normal conditions returned, and if so, could they look to powdered fuel to help them? He should certainly follow up this subject with much interest to see if it offered a solution of some of their difficulties.

Mr. L. G. Hill.

Mr. L. G. Hill stated that having had some years' experience of pulverised fuel plant in this country as applied to the rotary kiln in the cement industry and, during the last two years, to steel furnaces, he agreed with the author as to the advantage claimed by the use of pulverised fuel. He understood the Bettington boilers had been fired this way for some years. One instance he had in mind was not so successful as it ought to have been owing to the inefficient method of grinding the coal. The practice described, viz., a preliminary crusher to bring down the coal to a convenient size, i.e., $\frac{3}{4}$ inch, then passing through a drier before milling, was usually necessary. The type of pulveriser used was a most important feature of the scheme. Once the coal was suitably pulverised and available in a large storage hopper,

it seemed to him unnecessary to have the system of screw conveyers, distribution blower, distributing pipe main, return main and air separator, etc., all of which took up a lot of room and must be expensive, as described on pages 80–81 with regard to the Holbeck system. Mr. L. G. Hill.

On page 105 a much simpler device was adopted in locomotive firing, where all the necessary plant for firing was contained in the few available feet of space between the hopper of powdered fuel on the tender and the firebox of the loco.

The application of the system to the cement industry was just as simple as that described for the locomotive and had been carried out successfully by his firm for very many years.

This was entirely due to the very efficient method of grinding the fuel, viz., to a fineness of 90 per cent. through a 200 × 200 mesh with a flocculent-shaped particle, which naturally remained suspended in the distributing current. He claimed that this efficient grinding would eliminate the expensive system of air separation and return pipe mains described in the Holbeck system, and consequently considerably reduce the initial cost of an installation, and also increase the efficiency.

Mr. T. D. Morgans said the author was to be congratulated upon his interesting and instructive paper. Any method which could be introduced with a view to bringing about the reduction of fuel for metallurgical processes was of national importance, especially with the present high price of fuel. Far too little attention was paid to the importance of regulating the supply of air for the combustion of fuel (apart from the loss of fuel caused by heating this excess of air, thereby reducing the flame temperature and temperature of combustion); the loss by oxidation in the case of metals was very great, resulting in many cases in the scorching of the metal, producing, in the case of steel, bars with rough edges or corners. Mr. T. D. Morgans.

Mr. T. D. Morgans.

Late combustion, again, was the cause of loss of fuel and products. Although powdered fuel might be used very successfully in many metallurgical processes he feared there were many objections to its satisfactory use for the open-hearth process :

(1) Effect on the life of the furnace itself.
(2) Effect on the process and finished products.

Taking the first point, the life of the open-hearth furnace depended upon or was controlled by the chequers. In an ordinary open-hearth furnace using producer-gas the life of these chequers was about 12 months or, say, 500 to 550 heats, but with the large quantity of ash that would be blown into the chequers by the use of powdered fuel the life of the furnace would be reduced to probably about 250 heats, which would be a serious matter in cost and loss of output. With regard to the second point, the ash in the powdered fuel would have a most serious effect upon the quality of the steel, especially steel made by the acid process. Assuming the coal to contain 1·00 per cent. sulphur, and the composition of pig iron and scrap to contain 0·05 per cent., could the author say what proportion of the sulphur in the coal would pass into the steel, or, in other words, what would be the sulphur in the finished steel ? In ordinary working with producer-gas, with coal with 1·00 per cent. sulphur, the sulphur taken up by the steel from the gas would amount to 0·006 or 0·008 per cent., and it was most important that fuel with not more than 1·00 per cent. sulphur should be used, with the use of minimum size steam jets and good solid well-fed fires. Again, it appeared to him that when using powdered fuel less oxidation of the elements in the charge would take place during the melting period. In ordinary producer practice about 60 per cent. of the carbon was eliminated during the melting period, and he feared that the

process would be greatly retarded by using pulverised fuel. Could the author give some information on this point? Assuming two furnaces working on similar proportions of pig iron and scrap, but one with producer-gas and the other with powdered fuel, what would be the relative speed of working or time taken to work or charge in each case? Without doubt powdered fuel could be used with success in a furnace of a non-reversing type, if sufficient heat could be maintained without regenerators. With well-equipped plants with coke-ovens and blast-furnaces the ideal thing was to do all the heating and melting from the waste gases from these processes, therefore the only works who would consider the using of powdered fuel would be those without either coke-ovens or blast-furnaces. Again, could the author give information as to whether it was necessary to have freshly ground fuel? Would it be possible to use up what might be called natural coal-dust from mines? **Mr. T. D. Morgans.**

In conclusion, he thanked the author for his paper, and sincerely hoped that members might have many such papers where mining and metallurgy were so closely allied.

The discussion was adjourned.

PROCEEDINGS.

Special General Meeting, Thursday Evening, April 28, 1921.

A Special General Evening Meeting of the South Wales Institute of Engineers was held at the Institution, Cardiff, on Thursday, April 28, 1921.

The President, Mr. W. Forster Brown, M.Inst.C.E., occupied the chair.

The minutes of the 63rd Annual General Meeting held on Thursday, March 17, 1921, were read and confirmed.

The Law of Support.

By David Bowen, F.G.S., M.I.Min.E., F.S.I., Barrister-at-Law.

The President. The President stated that their chief purpose in meeting on that occasion was to hear a paper upon a subject which, although a legal subject, was closely associated with the work of mining, and, therefore, of considerable interest to many members of that Institute. In view of the subject-matter of Mr. Bowen's contribution, an invitation had been extended to a number of legal gentlemen whose professional practice had intimate relations with the operations of the South Wales coalfield, and on behalf of the Council he had pleasure in welcoming those who had accepted the invitation. He trusted that after Mr. Bowen had given them a synopsis of his paper, they would express their views freely upon the points with which the paper dealt.

THE LAW OF SUPPORT.

By David Bowen, Barrister-at-Law.

THE LAW OF SUPPORT.*

By David Bowen, Barrister-at-Law.

1. Introductory.

This subject is one of very considerable importance to the mine-owner and mining engineer. There is, perhaps, no question so intimately connected with the work of the miner and which so materially affects mining operations as the necessity for providing support and the prevention or regulation of subsidence of the strata overlying the particular seam being worked. The economical exploitation of the minerals and the support of the superincumbent strata are the two main determining factors in the choice of the method of working; and this fact comes into greater prominence in view of the new complications incident to mining at greater depths.

Surface land or an underground seam in its natural state enjoys vertical or subjacent support from the soil or strata below, and lateral or adjacent support from the adjoining soil or strata. If the land which receives and the land which affords support form separate tenements, the owner of the former may be entitled to a right of support as against the owner of the latter; that is to say, the one has a right in law to have his land supported independently of anything which the other may do in his own land in the exercise of his proprietary rights.

* This paper has also been read and discussed by the South Staffordshire Institute of Mining Engineers, and is printed in the *Transactions of the Institution of Mining Engineers*, 1920–1921, vol. lxi. p. 47.

This right of support may be natural or acquired. The natural right is that which is incident to land unincumbered by buildings and in its natural state. The acquired right comprises the right to the increased measure of support required to sustain the weight of buildings, or the modified measure of support required by works such as railways, canals, or waterworks, or even by land whose natural stability has been diminished by excavation either within the land itself or in the neighbourhood. The natural right is so-called because it is a natural right incident to the right of property in the land; it is a right of property analogous to the right of a riparian owner to the flow of a natural stream; it does not originate in grant. The artificial right, as it is sometimes called, is acquired by grant or under some of the presumptions which in law supply the place of grant. But although the rights thus differ in their origin, their character is in each case the same; the acquired right is inseparable from, and, as between the parties to the instrument of severance, is a mere enlargement of the natural right.

The right to support of a surface owner as against a mineral owner imposes upon the latter an obligation not to injure his neighbour's property by subsidence. But the obligation does not confer upon the surface owner a right to have the minerals retained *in situ* for his protection. The mineral owner is entitled to enjoy his minerals according to their natural mode of user, so long as he does not infringe the maxim *Sic utere tuo ut alienum non lædas*; the getting of minerals without negligence and in a proper course of working is not an unlawful act; accordingly the mineral owner may dig into or even remove the whole of the minerals if the soil above does not fall. The obligation to support may be fulfilled by the substitution of artificial support.

The right of support to the surface upon the minerals is independent of the nature of the strata, or the difficulty of

propping up the surface, or the comparative value of the surface and the minerals. Therefore there is no such thing as a right to a *reasonable* support for the surface. It is impossible to measure out degrees to which the right may extend, for there is no standard by which the reasonableness of the support from underlying strata can be gauged. The only reasonable support is that which will protect the surface from subsidence and keep it securely at its ancient and natural level.

It follows that the surface owner's right is not modified by the fact that the obligation not to cause damage by subsidence renders the effectual working of the mines impossible; this may happen in the case of coal-mines from the extent of pillars required for support, or in the case of metalliferous mines owing to the irregular distribution of the ore making it impossible to calculate and set out pillars. There is likewise no modification of the surface owner's right if the supported land contains strata of an unstable nature which escape and cause subsidence if the adjoining owner excavates his land. Instances occur in the case of pitch which becomes soft and oozes out when exposed to the atmosphere; and in the case of running silt.

It has been questioned whether the degree of support for underground strata is the same as for the surface, and opinion on this point appears to be somewhat divided. One school holds that the reasons for inferring an absolute right of support for the surface apply with equal force in the case of the upper of two seams. The other school doubts whether this reasoning applies without some modification, on the ground that the effect of withdrawing support is or may be very different in the two cases. Subsidence of the surface may mean ruin; subsidence of an upper seam may only result in increased expense in working it.

The presumption that the surface-owner has a right to

support for his land may, of course, be rebutted by evidence to the contrary. If there is no instrument defining the respective rights of the surface-owner and the owner of the subjacent or adjacent land, the presumption will, in general, be absolute. It may in some cases be rebutted by evidence of a right by custom or prescription to work the minerals without leaving support. Generally, however, if a right to withdraw support exists, the power to do so has been conferred upon the mineral owner by the instrument of severance.

The presumption is independent of the manner of severance. It applies equally whether severance has been effected by a grant of mines and minerals apart from the land, or by a grant of the land with an exception of the minerals. The form of the instrument is immaterial ; it may be a grant in fee simple ; or it may be a lease for a term of years ; or it may be an Inclosure Act or Award. So strong is the presumption in favour of the surface-owner that a right of working the minerals so as to withdraw support will only be inferred if the language of the instrument, either by express words or by necessary implication, unequivocally conveys that intention.

The artificial right of support is not an incident but is a distinct right of property which can only be acquired by grant or by some means equivalent in law to grant. It may be acquired by grant, express or implied, or under the doctrine of prescription, and when acquired it is, in general, an enhancement or enlargement of the natural right.

A right of support for artificial structures is frequently created by statute, as where railway companies, canal companies, and other like undertakers are empowered to construct and maintain works of public utility in the lands of private owners. The general rule on this head of law is, that where the legislature gives power to a public body to do anything of a public character, the legislature means also to give to the

public body all rights without which the power would become wholly ineffective. Accordingly, if support from subjacent mines is necessary the grant of a right of support will be presumed unless the provisions of the statute negative the inference.

An express grant or reservation of the artificial right to support is not of frequent occurrence; but the same object is often attained, in mining leases, by inserting a covenant which binds the lessee not to work a certain area, or to leave specified pillars for the support of buildings. The restriction thus imposed differs from a right to support, being more extensive in some respects and less so in others. Where a mere right to support exists, the mineral owner may work all the minerals provided he substitutes adequate artificial support. But where a restriction is imposed by covenant, the lessee is prohibited from working or getting the minerals within the specified area, irrespective of whether it is more or less than is in fact required for the support of the buildings, and whether or not substituted support is supplied by artificial means. Sometimes the requisite pillars are excepted from the demise.

A right of support for buildings arises much more frequently under the doctrine of implied grant than by express grant. It differs from a fetter imposed upon the working of mines in that it does not prohibit working within any area; the mine-owner, as in the case of the natural right, is free to work in a usual and proper manner, provided he substitutes artificial support.

The right of support for buildings from subjacent or adjacent soil may be acquired by prescription where it has been enjoyed from time immemorial, or under the presumptions which, in law, supply the place of prescription when length of enjoyment has been less than immemorial.

2. Right to Withdraw Support.

A right to work mines so as to let down the surface is capable of grant; no particular words are necessary; they may take the form of a covenant, but if they are susceptible of interpretation as a grant, the grant is valid. Such a grant does not operate as a release of the right to support which exists *ex jure naturae*; it operates as a grant of a right in the nature of an easement over the surface. The right may be created by the instrument of severance or by a separate and independent instrument. A power to withdraw vertical support does not confer upon the mine-owner who also owns the lateral mines the right to withdraw lateral support.

The right to withdraw support may be conferred upon the mine-owner by express words; but more frequently it arises by implication. Where the words are not express, the right will only be inferred if the language of the instrument, either in itself or interpreted in the light of admissible evidence as to the circumstances of the case at the time when the transaction was entered into, unequivocally conveys the intention to confer a power to withdraw support.

3. Construction of Instruments.

There are two main presumptions which govern the construction of mining instruments with regard to support: (*a*) it is to be presumed that the surface owner intended to reserve the right of support for the surface; (*b*) it is also to be presumed that the minerals are to be enjoyed. That the first of these is the ruling presumption has been established in a series of decisions culminating in that of the *Butterknowle Colliery Co.* v. *Bishop Auckland Industrial Co-Op. Soc.* (1906), A.C. 305. These cases relate to support from coal-seams, and underlying them all is an assumption that working in a com-

mercial sense is possible notwithstanding the obligation to leave support, so that effect can still be given to the second presumption. In many cases the assumption is contrary to fact; and it was not till the case of *Butterley Co.* v. *New Hucknall Colliery Co.* (1909), 1 Ch. 37; (1910) A.C. 381, that the impossibility—to the knowledge of the parties at the date of the instrument of severance—of working at all without causing subsidence was by proper evidence brought before the Court. The result is to increase the weight of the presumption in favour of the mine-owner in cases where that evidence is available.

The evidence in the *Butterley case* went to prove that subsidence inevitably follows the working of minerals in seams except at shallow depths, and that this subsidence is independent of the method of extraction adopted, though differences in method of extraction may produce differences in the evenness and regularity of the subsidence. In the case of *Welldon* v. *Butterley Co.* (1920), 1 Ch. 130, the evidence went to prove that no exception could be made of shallow seams; that subsidence inevitably occurs whatever the depth of the mineral excavations. A passage in the decision that 'there is no method by which coal can be so worked as not to cause subsidence' would appear to need some qualification. It is undoubtedly true that in old times methods of working were practised by which the greater proportion of the coal was abandoned in the form of pillars in order to support the roof, and subsidence was avoided. It is perhaps true that under the changed conditions of modern times it is impossible to work profitably any seam of coal by a method which would leave intact about 70 per cent. of the mineral, and that the passage in the decision in *Welldon* v. *Butterley Co.* is accurate on that assumption. On this point it is important to remember that each decision is a decision on

the facts of the particular case in question and cannot be applied without question to other cases.

The propositions which had been established up to the time of the case of the *Butterknowle Colliery Co.* v. *Bishop Auckland Industrial Soc.* are stated in that case by Lord Loreburn in the following terms: 'Whenever the minerals belong to one person and the surface to another, the law presumes that the surface owner has a right to support, unless the language of the instrument regulating their rights, or other evidence, clearly shows the contrary. In order to exclude a right of support, the language used must unequivocally convey that intention, either by express words or by necessary implication. For the same presumption in favour of a right of support which regulates the rights of parties in the absence of an instrument defining them will apply also in construing the instrument when it is produced. If the introduction of a clause to the effect that the mines must be worked so as not to let down the surface would not create an inconsistency with the actual clauses of the instrument, then it means that the surface cannot be let down.' In construing any instrument, therefore, if there are no express words reserving the right to support or granting the power to let down the surface, the test to be applied is this: Apply to the instrument a clause to the effect that the mines must be worked so as not to let down the surface; if this clause is inconsistent with the actual clauses of the instrument, then power to let down the surface will be implied; if there is no such inconsistency, then power to let down the surface will not be implied.

In the same case Lord Macnaghten said 'The result seems to be that in all cases where there has been a severance in title and the upper and lower strata are in different hands, the surface owner is entitled of common right to support for his property in its natural condition without interference or

disturbance by or in consequence of mining operations, unless such interference or disturbance is authorised by the instrument of severance either by express terms or by necessary implication.' And Lord Davey said 'It cannot now be disputed that *primâ facie* where the surface is in one owner and the minerals in another the latter cannot work the minerals so as to destroy the surface.'

Lord Loreburn continued: 'Illustrations are numerous in the reports. Words, however wide, that merely authorise the getting of all the minerals, have been held not to authorise so getting them as to let down the surface. Where power is given to get the minerals on paying compensation for damage done to the surface, the Court will still scrutinise the compensation clause. Are there any rights belonging to the mine-owner on the surface (such as a right of making roads) to which the compensation clause may refer? If the compensation clause is capable of being satisfied by reference to acts done *on* the surface, then, though it may be wide enough to cover also damage done *to* the surface by taking away the support, still it must be confined to damage done *on* the surface, and the inference that support may be taken away on payment of compensation will not be drawn. Again, Courts have asked whether the compensation is manifestly inadequate for such an injury as letting down the surface and have commented upon the absence of any provision for compensation. Either of these circumstances has supplied judges with a reason for so cutting down wide language in a grant of minerals as to imply a condition that the surface shall be supported. The process of reasoning in such cases seems to be that parties must not be supposed to have intended what would be unreasonable and unjust. I think that in each of them a clause providing for a continuance of support would not have been inconsistent with the actual clauses.'

In those statements the *Butterknowle case* summarises in authoritative manner the results of previous decisions, notably *Davis* v. *Treharne* (1881), 6 A.C. 460; *Dixon* v. *White* (1883), 8 A.C. 833; *Love* v. *Bell* (1884), 9 A.C. 286; and *New Sharlston Collieries* v. *Westmoreland* (1900) (1904), 2. Ch. 443 n., in the House of Lords. On the assumption of the possibility of working without causing subsidence, they lay down an authoritative rule of construction, namely, that general powers of working are not sufficient *per se* to exclude the right of support.

In the *Butterley case* the question under consideration was the support of an upper seam by an underlying seam, but the case was decided on principles which apply equally well, and have since been applied, to support of the surface (see *Locker-Lampson* v. *Staveley Coal and Iron Co.* (1909), 25 T.L.R. 136; *Jones* v. *Consol. Anthracite Collieries* (1916), 1 K.B. 123; *Bank of Scotland* v. *Stewart* (1891), 18 Ct. of Sess. Cas., 4th S., 957; *Anderson* v. *M'Cracken Bros.* (1900), 2 *ibid.*, 5th Series, 780). The evidence was clear that the law of inevitable subsidence was known to the parties at all material times. The instrument of severance showed an intention that the underlying coal should be worked; it was therefore a necessary implication that subsidence was contemplated. In these circumstances, qualification of the powers of working in a mining instrument means no working at all, and would stultify the intention of the parties: the qualification would in fact render the instrument inoperative.

The case is thus distinguished from the *Butterknowle case* and cases of that type. On the assumption thus made the qualification of the general powers of working did not render the instrument inoperative—working was still possible and effect could be given to the intention of the parties, having regard to the interests of both. But there is another distinguishing feature. Support for the surface is so important

that judges have spoken of the withdrawal of support as amounting to destruction of property in the surface. In the *Butterley case,* however, it was shown that the withdrawal of support would result only in subsidence with a slight increase in the cost of working. In these circumstances it was easier to make the inference of a right to withdraw support.

The presumption in favour of the surface owner is not affected by the nature of the instrument of severance. It holds good whether it be a lease, a deed of grant, or of reservation, or an Inclosure Act or Award.

It is well settled, therefore, that the mere fact of giving very wide general powers to sink pits and to work, get, and carry away minerals does not of itself establish a right to get rid of the common law right of the surface owner to have his surface undisturbed. Something more must be found from which the necessary implication may be made.

(*a*) The necessary implication may be made from the reservation of powers which existed before the severance. In *Beard* v. *Moira Colliery Co.* (1915), 1 Ch. 257, lands were granted by an owner in fee in 1829. The conveyance excepted all the mines and minerals under the land granted, and reserved full and free liberty to enter upon the land, to sink pits and shafts, and to exercise all other powers of working and getting the minerals 'in as full and ample a way as if these presents had not been made and executed.' There was also provision for payment by the grantor of compensation for damage or injury done in the exercise of the reserved powers. Here there was a necessary implication from the language used, that the grantor should have a right to let down the surface if he was to be able to work and carry away the coal in as full and ample a manner as before conveyance. The grantor, being owner in fee, if he had not made and executed the conveyance, would have had a perfect right

to let down the surface, while working the mines, and unless after the conveyance he retained that right he would not have been able to work and carry away in as full and ample a way and manner as before the conveyance.

This decision of the Court of Appeal set at rest a point which had been in doubt with regard to *Chamber Colliery Co.* v. *Twyerould* (1915), 1 Ch. 268 n. In that case Lord Watson, in delivering the judgment of the House of Lords, treated it as a question of some nicety whether similar words were sufficient to oust the common law right. Admitting that the words were capable of that meaning, he found other provisions of the instrument which, in conjunction with these words, he held to exclude the right of support. With reference to this case, Lord Halsbury in the *New Sharlston case* expressed an opinion in favour of the view that the words in themselves were sufficient to ' carry you the whole way.'

In these judgments the Court of Appeal also refused to apply to the interpretation of such words the rule that has been adopted in the interpretation of similar words in cases upon Inclosure Acts, importing that the Lord of the Manor shall enjoy his property as freely as if the Act in question had not been passed. Such words have been treated practically as a dead letter. The rule has been explained as resting upon the change in the nature of the commoner's interest by the Inclosure Act; and there is no ground for extending it to the construction of deeds, where ordinary words ought to be given their plain and ordinary meaning.

(*b*) The necessary implication may also be made where there is evidence from which it can be inferred that the parties have entered into the contract with the knowledge that it was impossible to work without causing subsidence. Such knowledge may, of course, be admitted or proved, but more generally it will be a matter of inference from evidence of mining practice

at the date of the instrument. Whether such evidence is available will depend on the date of the instrument, but the law of inevitable subsidence has been known to mining engineers for many years, and this principle probably applies to most modern mining instruments.

In the case of *Butterley Co.* v. *New Hucknall Colliery Co.* there were five leases beginning in 1887 of an upper seam of coal. The leases reserved power to work underlying seams with various privileges over the works of the upper lessees : there were also obligations upon the upper lessees not to interfere with the working of the lower seams, and it was thus clear that the parties contemplated that the lower seams should be worked during the currency of the upper leases. It was proved or admitted that the usual system of working in the neighbourhood was by longwall, and that this system was the best and most profitable. It was also proved that it was impossible to work at all without causing subsidence. There was no dispute that these facts were within the knowledge of the parties at the date of the leases. It was further shown that the working of the lower seam concurrently with the upper would not result in the destruction of the upper seam, but would only cause subsidence and slightly increase the cost of working. In these circumstances, working without causing subsidence meant no working at all, to the knowledge of the parties ; there was, therefore, by necessary implication a right to let down, otherwise the intention of the parties that the lower seam should be worked concurrently with the upper would be stultified : the right to work would, in fact, be inoperative.

The same principles were later applied in respect of the withdrawal of support from the surface in the case of *Locker-Lampson* v. *Staveley Coal and Iron Co.* (1909), 25 T.L.R. 136. By a lease dated July 25, 1871, certain seams of coal under

lands in Derbyshire and Yorkshire were demised to the defendants. The lease contained covenants to work the collieries in a proper and workmanlike manner, and according to the best and most improved methods until the seams of coal should be exhausted; to leave ribs and pillars of coal for the support of the shafts and buildings of the mine; to leave sufficient coal for the support of houses and buildings on the surface; and to pay to the lessor and his tenants compensation for any damage done by carrying on the mining operations. The defendants and their sub-lessees in a proper course of working, worked on the longwall system, and caused a subsidence of the surface. In 1871 the longwall system was the universal method of working in the district, which fact must have been known to the parties and their agents at the date of the lease. It was held that the lessees were entitled to work so as to withdraw support from the surface.

Another instance occurs in relation to a lease of mines in Wales in the case of *Jones* v. *Consolidated Anthracite Collieries* (1916), K. B. 123. In 1896 the owner of land granted a lease of coal under certain land, with power to sink pits and work. The lessee covenanted to win and work the mines regularly, and according to the best and most approved mode of working similar mines in the district. It was proved that for the last fifty years the collieries in the district had worked on the longwall system; that under this system the surface necessarily and inevitably subsided as the result of the working; that a similar result followed under the pillar and stall system of working; and that this fact had been common knowledge for at least forty years. It was found as a fact that at the date of the lease the parties knew that the seam could not be worked on the system universally used in the district, or indeed any other system without some subsi-

dence. There was, therefore, following the *Butterley case*, a power to let down the surface; the principle of that case being that a man who has granted a right to work a mine must be taken to allow its being worked in the only way in which it can be worked, whatever the effect on his other property may be.

In the case of *Buchanan* v. *Andrew* (1873), L.R., 2 Sc. and D. 286, a feu of lands was granted, excepting the mines, and the contract provided that the superior should not be liable for any damage which might happen to the land or buildings thereon, by the working of the minerals under the same, or in the neighbourhood thereof, under the longwall system or otherwise; it was conceded that subsidence was inevitable, and it was accordingly held that a power to let down was implied.

The *Butterley case* seems to affect the meaning to be attached to covenants to work. With reference to the lease of the upper seam in that case, Lord Atkinson said that when the lessees covenant as they do, that they will during the term of the lease 'use and work the said seams, veins, and mines of coal, and substances hereby granted and demised, fairly and regularly according to the best and most improved methods now being or hereafter to be in use, and in a workmanlike manner in all respects,' it is scarcely possible, in the face of the evidence, to suppose that it was not intended to authorise, if indeed not enjoin, the lessees to work the mines on the longwall system.

With this may be contrasted the remarks of Lord Hatherley, when Vice-Chancellor, with reference to a similar covenant in the case of *Shafto* v. *Johnson* (1863), 8 B. and S. 252 n., at p. 256. In the district in question the usual mode of working was by pillar and stall, and it was the practice to work away the pillars. He considered that a covenant to

work according to the best and most approved method of working collieries of a like nature in the district only meant the best and most approved method of working which would be consistent with the other terms and provisions of the lease and the other legal rights of the parties. If the lease conferred a right to work the pillars, the covenant bound the lessee to do so by the most approved methods, but the covenant did not of itself give him the right to work the pillars.

A similar idea underlies the remarks of Lord Selborne in *Buchanan* v. *Andrew* and *Davis* v. *Treharne*. In the latter case he considered that a covenant to work in 'the most usual and approved way of working' in the county, related to the manner of working the mine for mining purposes; the words did not affect the collateral obligation to afford support. There could not possibly be any local custom in such a district to disregard the right of a surface owner who was not lessor of the mines; and there was no difference in the position if the surface owner was also lessor.

In a lease there may be imposed upon the lessee an obligation to perform certain acts which are plainly inconsistent with supporting the surface. Thus in the case of *Shafto* v. *Johnson* there was a covenant to work 'so as to produce the greatest quantity of merchantable coals from out of each and every the workable seams,' coupled with provisions for the safety of the mine. Lord Hatherley considered that so far the intent of the lessor was, that the lessee should get the greatest quantity of coal without damage to the mine, still reserving his general right to have the surface supported. At most there was an indication that the parties contemplated a power to let down. There were, however, further provisions including the prohibition of working under a certain area, the object of which was to create absolute protection for that part. When the two classes of covenants

were coupled together the necessary inference followed that there was an intention that all the coal that could be got without damage to the mine should be got; provided always that certain specified property and that alone should be protected and supported. When a large part was protected, the inference was irresistible that the part not specifically protected might be let down.

The protection of a specific area by the absolute prohibition of the working of minerals thereupon is not, however, inconsistent with the continuance of the common law right of support outside that area. Thus in *Dugdale* v. *Robertson* (1857), 3 K. and J. 695, there was a lease of the mines under 514 acres of land with full powers to work, except in or upon any demesne lands and pleasure grounds belonging to and occupied with the mansion, measuring four acres. It was held that working was absolutely prohibited within the four acres, and that no right was granted to work outside that area so as to withdraw support from such land and buildings.

On the other hand, as has been seen in the case of *Shafto* v. *Johnson*, if there is anything in the words of the working powers to suggest a right to let down, the protection of a specific part of the surface may strengthen the inference of a right to withdraw support from the remainder. So in the case of *Chamber Colliery Co.* v. *Twyerould*, where mines were granted with power to work as the grantor 'could or might have done in case these presents had not been made,' it was considered that the inference of a right to let down, which the words in parentheses were capable of bearing, was strengthened by a provision which excepted from the grant the coal under certain buildings and yards. The provision was not *per se* conclusive; but it did indicate an apprehension on the part of the grantors that, but for the reservation, their existing buildings would be exposed to serious risk of injury in the course of working

contemplated. It was a precaution absolutely necessary for the protection of these buildings from injury, if their grantees had power to work out the whole of the minerals. If the grantees were under an obligation to leave sufficient mineral to support the surface, there was no imperative, if any, necessity for it.

In the case of *Brewer* v. *Rhymney Iron Co.* (1910), 1 Ch. 766, the question arose as to the nature of protection to buildings under a covenant not to injure or endanger buildings, in leases which did not prohibit working under buildings but authorised working according to the most improved system in the neighbourhood, and also bound the lessees by covenant to work according to the best mode of working for the time being adopted in the neighbourhood, and so that all the marketable coal therein capable of being got according to the custom of working in the neighbourhood might be fairly and properly worked. There was also a provision for compensation for surface damage. The method in general use in the district was the longwall system or a modification thereof. It was held that the lessees had a right as against the lessors to extract coal so as to let down the surface, provided that they made compensation for surface damage, and did not injure or endanger buildings on the surface. The leases could not be construed as conferring the right to let down the buildings doing no unnecessary damage, for this would be, in effect, to ignore the special covenant as to buildings and leave them in precisely the same position as the general surface.

4. Compensation Clauses in Instruments.

Where the power of getting the minerals is made subject to the payment of compensation for surface damage, the scope of the compensation clause may, in the absence of evidence as

to inevitable subsidence, be material in considering the extent of the working powers granted or reserved.

It is not the function, and presumably is not the intention, of a compensation clause to define or extend the powers of working; and, in fact, a clause providing that the mine-owner shall make compensation for damage to the surface does not itself afford a strong argument for saying that he may destroy the surface, as there may be other injury to the surface in connection with the working of the minerals to which the clause will be applicable.

It is not enough, then, to rebut the presumption of support, that compensation is provided in measure adequate or more than adequate to cover any damage likely to be occasioned by the exercise of the powers and privileges granted or reserved by the instrument of severance. The Court will consider whether there are any rights belonging to the mine-owner on the surface (such as the right of making roads, making spoil-banks, etc.) to which the compensation clause is capable of being satisfied by reference to acts done *on* the surface; then, though it may be wide enough to cover also damage done *to* the surface by taking away the support, still it must be confined to damage done *on* the surface, and the inference that support may be taken away on payment of compensation will not be drawn.

But even if the provision for compensation is general and is wide enough to cover damage by subsidence it may only provide a cumulative remedy in covenant for the wrongful withdrawal of support, if injury is in fact caused; or it may apply to damage arising from accident or negligence in the exercise of the powers of working.

It may be, however, that no surface powers are exercisable to which the provisions for compensation can refer: it may then be possible to refer the compensation clause only to injury from subsidence, or the clause may specifically refer to injury

by subsidence. In such case, it is a reasonable if not a necessary inference that subsidence is authorised. As Lord Blackburn said in *Davis* v. *Treharne*, the conclusion is very strong from such facts that the lessor has authorised letting down the surface.

It is not clear how far these principles are reconcilable with later *dicta*. In *New Sharlston Collieries* v. *Westmoreland* Lord Davey said: 'Speaking for myself, I cannot see why a covenant providing a particular measure or mode of compensation is in any way inconsistent with the existence of an obligation not to let down the surface, even though that covenant extends beyond the surface, and is applicable also, or even exclusively, to underground operations. The use of the words "by reason of the exercise of the powers" does not seem to me to carry it any further, because it may apply to any incidental injury done—whether accidentally or wilfully makes no difference—whilst exercising the powers. It does not seem to me to give a licence to do the injury if you say that a person shall pay compensation if he does it. A covenant to pay compensation for doing a thing which you are prohibited from doing is in no way contrary to or inconsistent with the continuance of the obligation not to do it. Therefore I do not accede to the argument that the existence of a covenant for payment of compensation for letting down the surface is, whether it applies wholly or partially to underground operations or not, in any way inconsistent with the continuance of the common law obligation.'

These remarks were subsequently explained by Lord Davey in the *Butterknowle case*. He there stated that he did not intend to say more than what he understood Lord Blackburn to have meant in *Davis* v. *Treharne*. 'If the words mean that the owner of the coal may take away the whole coal regardless of the consequences, on making compensation for the injury

done, the law will give effect to such a bargain or enactment,' but a general compensation clause does not itself afford a strong argument that the miner may destroy the surface. It would appear therefore to be the meaning that a clause specifically dealing with compensation for damage by subsidence, in conjunction with other provisions, may lead to an inference that subsidence was contemplated.

Although provision for compensation is not of itself sufficient to show that the mine-owner working in the usual and proper manner is at liberty to let down the surface, the absence of any provision for compensation is some indication that the ordinary rights of the surface owner were intended to be left untouched. On the other hand, the presence of a provision for compensation, which is obviously inadequate, or plainly inappropriate if applied to damage by subsidence, is cogent evidence to prove that subsidence was not contemplated.

The principles stated above are illustrated by the decisions in *Harris* v. *Ryding* (1839), 5 M. & W. 60 ; *Smart* v. *Morton* (1855), 5 E. & B. 30 ; *Davis* v. *Treharne* (1881), 6 App. Cas. 460 ; *Dixon* v. *White* (1883), 8 App. Cas. 833 ; *Sitwell* v. *Londesborough* (1905), 1 Ch. 460 ; *Smith* v. *Darby* (1873), 7 Q. B. 716 ; *Aspden* v. *Seddon* (1875), 10 Ch. App. 394 ; *Chamber Colliery Co.* v. *Twyerould* (H. L., July 20, 1893, not reported) ; *New Sharlston Collieries* v. *Westmoreland* (1904), 2 Ch. 443, 446 ; *Williams* v. *Bagnall* (1867), 15 W. R. 272.

5. Inclosure Acts.

Before Inclosure, the lord is entitled *primâ facie* to work the minerals in the waste of the manor : unless his rights are restricted by custom, the only limitation upon his powers of working is that imposed by his liability to leave a sufficiency of common for the commoners. But after Inclosure, the

position is changed. An Inclosure Act is really nothing more than an agreement between the parties, sanctioned by the Legislature. Before the Act, the land down to the centre of the earth belongs to the lord ; he agrees to the Act, and if the minerals are excepted he places the allottee of the surface of the enclosed waste in the same position as if it had been ancient enclosed land and the lord had alienated the surface reserving the minerals. The allottee acquires a right of support unless otherwise provided, and *primâ facie* the owner of the minerals must work them in a way so as not to damage the extended interest which the commoner has acquired under the Act.

The principles which govern the construction of a common law grant of land with an exception of mines in questions of support apply accordingly to the construction of Inclosure Acts. It is doubtful, however, if the effect of deep workings had been accurately ascertained when the private Inclosure Acts of the eighteenth century were passed. The actual decisions upon such Acts would appear, therefore, to be unaffected by the principles laid down in *Butterley Co.* v. *New Hucknall Colliery Co.* ; but the principle seems, however, to have been recognised in *Bell* v. *Dudley* (1895), 1 Ch. 182.

As in the case of a common grant, the reservation of powers of working the minerals, expressed in general terms, are not sufficient to rebut the presumption in favour of the allottee. Nor is it enough that there are reserved to the lord powers of working as fully and freely as if the Act had not been passed. Such a provision does not mean that the lord can destroy the surface as he would have been able to do when the common was waste land ; the provision must be interpreted with regard to the changed interest of the commoners. As Lord Macnaghten said in the *Butterknowle case*, 'The difficulty of applying such a hypothesis to the altered condition of things brought about

by an Inclosure Act has, it seems to me, led this House to treat the provision in which it was found, and of which it would seem at first sight to be the keynote, as a dead letter for any practical purpose.' But from Lord Halsbury's observations in the *Butterley case*, if 'misled' had been substituted for 'led,' this observation of Lord Macnaghten would have been more accurate.

Since the principles which apply in considering the effect of a compensation clause in a common grant also determine the effect to be attached to the presence or absence of a means of compensation in an Inclosure Act, it is unnecessary to discuss this question in detail in this paper.

6. The Law of Support in Relation to Statutory Undertakings.

'A vendor, on selling part of his property, is presumed to grant such a measure of support from the property he retains as is necessary for the property sold in its then condition, or when applied to the purpose for which the grant was expressly made; but the precise measure of such support depends upon the special circumstances of each case' (see Dart: 'Vendors and Purchasers,' vol. i. p. 422). Applying this general principle to the case of statutory undertakings, it follows that the rights of a corporation which acquires lands or erects works thereon in pursuance of statutory powers are the same as would be those of an ordinary individual, except so far as such rights are modified or varied by statute or by contract between the parties (see *Caledonian Railway Co.* v. *Sprot*, 2 Macq. 449; *Elliot* v. *N.E. Railway Co.*, 10 H. L. Cas. 333). Apart from cases coming within what is commonly known as 'the Mining Code,' the principle just enunciated is illustrated by several decisions in cases typical of Special Railway and Canal Acts

and similar Acts, antecedent to or replacing the Mining Code, and which need no elaboration here.

What is commonly known as 'the Mining Code' is a *fasciculus* of clauses contained in the Railways Clauses Consolidation Act, 1845, the Waterworks Clauses Act, 1847, and the Public Health Act, 1845 (Support of Sewers), Amendment Act, 1883. This code contains an absolute prohibition against the working of any minerals within a prescribed distance of any of the works of the statutory undertakers, except under certain conditions which will be stated presently. It has been described as the 'charter of the mine-owners' rights' within the prescribed distance, and defines the relations between mine-owners on the one hand and statutory undertakers on the other, where land is compulsorily taken in pursuance of statutory powers.

It will be convenient to summarise the position under this *fasciculus* of clauses in a series of propositions, as follows:

1. What is sold to the undertakers is the surface only; they do not acquire any minerals excepting only those as are necessary to be dug or carried away or used in the construction of their works, unless they are expressly purchased.

2. Minerals lying under the works or within the prescribed distance if any, may not be worked by the mine-owner until he has given notice of his intention so to work to the undertakers.

3. If the undertakers are not willing to treat for payment of compensation the mine-owner may, at the expiration of thirty days after notice given, proceed to work his minerals within the prescribed area.

4. If the undertakers, on the other hand, are willing to treat for payment of compensation, the mine-owner may not work the minerals compensated for at all, but he may, where his mines lie on both sides of the works, cut and make so many

airways, headways, gateways, or water levels through the mines within the prescribed area, as may be necessary to enable him to ventilate, drain, and work his mines on each or either side of the works.

5. Up to the moment when the mine-owner desires to work his mines within the prescribed area, the undertakers have every right of subjacent and adjacent support, but from the receipt by them of notice of the intention of the mine-owner to work such mines, the common law right of support, as far as the minerals within the prescribed area are concerned, is taken away, and the undertakers are left to such support as they may acquire by purchase or by payment of compensation as provided by the code.

I propose to deal with these observations in the order given.

1. Although the normal procedure is the purchase of the land without the mines, the mines may be included if expressly purchased, and such purchase may be made compulsorily or by agreement. Further, the mines may be purchased at any time, at the option of the undertakers, after the surface has been acquired, provided that such purchase takes place within the period limited for the exercise of their statutory powers. They may purchase the whole of the underlying minerals or a part only, at their option, but their compulsory power may only be exercised as regards the minerals within the prescribed area, and within the prescribed time. At the expiration of that time, they may purchase the minerals within such limits by agreement. It is to be noted that they may only purchase for the purposes of the works they are authorised to construct. It is unnecessary to consider here what meaning is to be attached to the term ‘ minerals ’ within the code.

2. When the mine-owner wishes to work the minerals within the prescribed area, he must give notice of his intention to the undertakers. The notice must be *bonâ fide*. There must

be not only an expression of desire but an honest actual existence of the desire to work either by himself or by his lessees to justify an owner in giving such a notice. The notice must be given thirty days before the commencement of the working.

3. If, at the expiration of thirty days from the receipt of notice of intention to work, the undertakers have not given the mine-owner a counter-notice to the effect that they are willing to treat with him as to the compensation to be payable for the minerals left unworked, then the mine-owner is at liberty to work and go on working the minerals, subject to the restrictions imposed by the code. The undertakers are not bound to any fixed period within which they *must* give a counter-notice. If at any time after the receipt of the notice of intention to work they fear damage to their works, they can stop the working of the minerals or the continuance of such working by a counter-notice of their willingness to pay compensation for the minerals which have not been worked, and which they desire to be left unworked. It appears that the undertakers may, if they think fit, give a counter-notice as to part of the minerals at one time, and another part at another time. Where compensation has been made for minerals left unworked, the minerals thus left do not become the property of the undertakers, but remain the property of the mine-owner. The only result is that neither the mine-owner nor the undertakers may remove such minerals. Where the mine-owner is at liberty to work the minerals within the prescribed area, as happens when the undertakers do not give counter-notice to treat for compensation within thirty days of notice of intention to work, working may only be done in a manner proper and necessary for the beneficial working of the minerals, and according to the usual manner of working such mines in the district where the same are situate; and if any damage or obstruction is occasioned to the railway or other works by

improper working of such mines, such damage or obstruction must be forthwith repaired or removed, as the case may require, by the mine-owner, or in default thereof the undertakers may make good the damage and recover the expense occasioned thereby from the mine-owner.

4. The headways, etc., which may be cut and made through minerals within the prescribed area, where compensation has been paid, are limited to the prescribed dimensions, or, where no dimensions are prescribed, to 8 feet in width and 8 feet in height.

Compensation is only claimable in respect of substances which are minerals within the code, and which lie within the prescribed area. This compensation can only be claimed by the person entitled to give notice of intention to work. Such compensation is full compensation, i.e. what the minerals would have sold for if worked, less the cost of working them. If the minerals have no value, or are unprofitable to work, there can be no right to compensation.

5. As to the right to support, it should be remembered that on a conveyance of the surface, excepting the mines, in the absence of any express words to the contrary, it is implied that the surface conveyed is entitled to the common law right to subjacent and adjacent support. Section 77 of the Railways Clauses Act, 1845, and section 18 of the Waterworks Clauses Act, 1847, however, are, in substance, clauses enacting that a special rule of construction shall apply to conveyances of land to statutory undertakers. They invert the ordinary rule of construction applied to ordinary conveyances as stated above. Either by themselves or in conjunction with the other clauses of the code, where the mines are not purchased, they have the effect of depriving the undertakers of all rights to support from the excepted mines. The code takes away rights of adjacent and subjacent support to some extent from and

after a particular moment. If the mine-owner wants his mines and is desirous of working them, then the moment arrives; and if the undertakers, upon notice, are unwilling to purchase the mines, then the mine-owner may, so far as is necessary for the enjoyment of his own mine, destroy the adjacent and subjacent support. (See *Ruabon Brick, etc., Co.* v. *G. W. Railway Co.*, (1893) 1 Ch. 454, 457, *per* Bowen, L.J.)

The rights given by section 78 (of the Railways Clauses Consolidation Act, 1845) to the railway company are in substitution for the common law rights of support, whether vertical or lateral, within the forty yards' limit. The general effect of this *fasciculus* of clauses is to establish on a statutory basis the reciprocal rights of the railway company on the one hand, and the owners, lessees or occupiers of mines lying under or near the railway on the other. These reciprocal rights are different from, and inconsistent with, the common law right of vertical and lateral support, and entirely replace those rights as between the railway company and the owners of the mines, so that on the one hand the railway company cannot claim those common law rights as against the mine-owners, nor can the owners of the mines claim that freedom of working which is compatible with the duties of support, and is, therefore, permitted by the common law. In return for this novel servitude imposed upon them by the legislature, the owners of such mines have sundry rights and privileges granted to them. These rights and privileges are given to them by statute and not by contract, and they are unaffected by any transactions between the railway company and third parties. (See *L. & N. W. Railway Co.* v. *Howley Park, etc., Co.*, (1911) 2 Ch. 109, 110, *per* Cozens-Hardy, M.R., and Fletcher-Moulton, L.J.)

As regards substances which are not under the land purchased, and are inside the prescribed distance and are not

minerals, the common law right, however, remains. As regards all substances, whether minerals or not, outside the prescribed distance, the common law right also remains. Prior to the decision in *L. & N.W. Railway Co.* v. *Howley Park, etc., Co.*, the dicta on the subject were not uniform, and some of them were obscure. In that case the defendants were lessees of minerals lying outside the prescribed distances, which they held from the successors in title from the vendor to the railway company. It was held that railway companies were entitled to the common law right of lateral support for their railway from such minerals. It was admitted that outside that distance no statutory notice could be given, and no counter-notice could be given; and it was held that the common law right was only taken away to the extent to which the notice and counter-notice could relate.

It is impossible within the limits of this paper to discuss in greater detail any of the particular decisions illustrative of the legal position under the Mining Code. What has been stated above is a sufficient general indication of the position, and may be applied broadly to particular cases which may arise.

The Discussion.

The President.

The PRESIDENT said he was sure they had all heard with keen interest Mr. Bowen's lucid statement. Before declaring the subject open to discussion, he might say that a number of letters had been received from gentlemen expressing regret at the writers' inability to attend the meeting. One of these was Mr. D. W. JONES, Merthyr, who in a letter to the Secretary wrote:

'THE LAW OF SUPPORT.

Mr. D. W. Jones.

'I beg to thank you for sending me an advance copy of the above paper by Mr. David Bowen.

'It is a lucid and admirable statement of the law upon the subject, and it would have given me great pleasure to attend the meeting if my other engagements had permitted.

'Having regard to the extent of the present-day mining operations, and the very serious damage done to surface properties, I cannot help thinking that the time has come for legislation upon the subject, and for establishing some scheme of compensation out of a fund contributed to by the colliery owner and the owner of the minerals.'

Mr. Charles Kenshole.

Mr. CHARLES KENSHOLE, called upon by the President, said in the first place he desired to thank the Council of the Institute for having invited him to the meeting, because

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the subject of the paper was of considerable interest to members of the legal profession as well as to mine-owners and mining engineers. He had to congratulate Mr. David Bowen upon a very excellent paper, which gave a lucid explanation of the Law of Support, and usefully cited the authorities upon which he based the conclusions he had arrived at. If he (the speaker) were asked to criticise the paper he should have great difficulty in doing so. Mr. Bowen's exposition of the conditions as to underground support—natural support and so forth—and his deductions from the decisions of the Courts were so correct that he could not put his finger upon any statement of the author's and say, 'This, or that, is not accurate or requires some qualification.' It seemed to him that the great difficulty they experienced in dealing with this question of support and subsidence lay in the varying conditions met with. Documents bearing upon the subject were rarely identical in terms; so that while they might have decisions upon certain facts placed before the Court, it frequently happened that they had cases to consider and determine which were not governed by those decisions because of the different conditions. Of course, as Mr. Bowen had mentioned, there was the cardinal principle of the right of support of the surface—that it had a natural right of support, which could not be withdrawn except under certain conditions either by express grant or by implication. Where documents gave wide powers of working the minerals—driving roads, etc., and working the minerals according to the ordinary practice of the district—laymen might well come to the conclusion that it followed that there was power to let down the surface, but standing alone such powers did not necessarily confer the right to let down the surface. What would be necessary to enable a person to let down the surface—and he thought the other

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legal gentlemen present would agree with him—was an express permission to do so. The lease should provide in addition to the extensive powers of working the minerals a reservation or grant of a right to let down the surface. Nothing less than such a specific reservation could confer the right unless it be by implication.

If by the latter, the question to be decided was the nature of the implication. Until the decision in the *Butterley case*, in, he thought, the year 1910, one really did not know what amounted to a sufficient implication. The *Butterley case* was a most important one. So far as he knew it was the first case coming before the Courts in which evidence was given as to the impossibility of working by longwall without letting down the surface. It was important to bear in mind the circumstances in that particular case, as described in Mr. Bowen's paper. There were leases of several seams, and, if he remembered rightly, the lease of the lower seam was granted first. When the lease of the upper seam came to be subsequently granted, express reference was made to the lease of the lower seam, and the lessee of the upper seam was under covenant to do nothing to affect the working of the lower seam. The lower seam was worked by longwall. Evidence was given that it was the practice of the district, and had been for a great number of years, to work minerals by the longwall method ; and evidence was also given that if the two seams were worked concurrently it must inevitably cause subsidence to the upper seam. Upon this the Courts came to the conclusion that it must have been within the contemplation of the parties that the continued working of the lower seam must cause a lowering of the upper seam. Now, the *Butterley case* had reference to the effect upon seams separately leased. Subsequently came the case—also referred

to by Mr. Bowen—of *Jones* v. *Consolidated Anthracite Collieries* (1916), from the western area of the South Wales coalfield. Here there was a lease of minerals and a separate lease of the surface, a condition generally found. Lord Dunraven first granted a lease of the minerals to the Consolidated Anthracite Collieries Co., Ltd., which lease contained the usual covenant that the lessee would work the minerals in a proper manner and in accordance with the practice of mining prevailing in the district. Subsequently Lord Dunraven granted a lease of the surface; and as a result of the working of the minerals, subsidence took place, causing damage to buildings on the surface. In the surface lease was a reservation of the minerals and a covenant by Lord Dunraven that he would make good any damage caused by subsidence. When subsidence actually occurred the surface lessee brought an action against the lessee of the minerals as well as against Lord Dunraven. In this case evidence was given that it had been the practice for fifty years in the Amman Valley to work by longwall, and that with the longwall method subsidence was inevitable. Mr. Justice Scrutton held that the mineral lessees were not liable for damages, inasmuch as they had followed the usual practice of working in the district, which inevitably caused subsidence, but that Lord Dunraven was liable under his covenant to the surface lessee to pay compensation. Thus in recent times there had been a great change with reference to the interpretation of the rights and liabilities of the mineral owner. Where a surface lease was taken with full knowledge that the longwall method of working was the practice of the district, he did not think the mineral lessee would be under any liability for surface damage caused by subsidence. Mr. Bowen had cited the *Howley Park case*, the decision of the House of Lords in which came as a great surprise to the mining

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world and the legal profession. The decision had a serious result in raising the question as to the point to which the owners of the minerals could safely work without withdrawing lateral support outside the forty yards, having regard to subsidence and damage to the railway. As most of his hearers were aware, this question had been recently considered by what was known as the Leslie Scott Committee. There had been joint consultations by representatives of the Mining Association and the railway companies, and the Leslie Scott Committee had put forward a recommendation as to the course to be adopted in the working of mines under railways. Generally, if his memory served him, the recommendation was this: where minerals were left within the 40 yards at the request of the railway companies, the mineral owners were to be paid compensation in accordance with the provisions of the Railway Clauses Act. Then, with reference to minerals outside the 40 yards, it was proposed that one-third of the compensation payable for the mineral left inside the 40 yards should be paid for the mineral left outside that area. There was, however, an important provision, namely, notice of intention to work must be given to the railway company, who must determine what minerals they desired should remain unworked; but if they did not give any counter-notice, the suggested arrangement was that the mineral lessees should be entitled to work the whole of the minerals both within and outside the 40 yards. If damage to the railway resulted, the railway company, the mineral lessee, and the mineral royalty owner should bear a certain proportion of the cost of remedying the damage, according to the depth of the mine. This was the recommendation; it was not yet the law. It was intended to get over the position created by the *Howley Park* decision of the House of Lords; and already in some instances arrangements upon these lines had been made between railway companies and

mineral owners. The suggested method would, at any rate, prevent large quantities of minerals being left unworked—an important matter to the community. In conclusion, he had only to say that Mr. Bowen's paper should prove a valuable work of reference. (Applause.) **Mr. Charles Kenshole.**

Mr. H. M. Ingledew said, if he might be allowed, as a very humble member of the lower branch of the profession to which Mr. Bowen belonged, and as a junior member of that Institute, to offer a few remarks on the paper, he should be proud. He wished to entirely associate himself with the words of Mr. Kenshole as to the value of the paper. Speaking personally, he did not know there was a single sentence in it which was incorrect from a legal point of view, or which could be criticised as conveying a wrong impression as to the law from the lawyer's standpoint. The Institute was greatly indebted to Mr. Bowen for dealing with a subject that was new as far as the Institute was concerned—an exceedingly difficult subject from the legal point of view—in such a clear and succinct manner. Having said this he was sure they would acquit him of any desire to criticise anything in the paper, and any remarks which he might make would be simply with the object of allowing the author perhaps to illuminate them further on this complicated subject by supplementing what he had so very well stated. As Mr. Kenshole indicated, the problem with regard to the Law of Support was really confined within a very small compass. There was the Mining Code in the Act of 1845, and the similar codes with reference to water and public sewers and that kind of thing applying to companies and others, and the ordinary common law rights of support applying to the ordinary individual. The chief difficulty, as he understood it, which arose from time to time in practice, was to ascertain exactly how the two principles contained in the common law right, and certain rights under the Mining Code, applied to the **Mr. H. M. Ingledew.**

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particular circumstances of each case. If he might say so, as one engaged in the rough and tumble of these matters, he quite agreed with Mr. Kenshole when he said that although the principles laid down by the courts were exceedingly valuable and must be mastered, yet their difficulties were only just beginning. The real difficulty was to apply principles to the almost innumerable differences of degree which arose in ordinary practice. It was a very fair basis to start on, that, after eliminating the main principles, the right of common law support, as the author so well stated in his paper, remained unless in the instrument of severance it could be shown that that right was taken away either by express words in the instrument itself or by words of necessary implication. The best illustration of 'necessary implication,' he thought, was contained in the case of *Jones* v. *Consolidated Anthracite Collieries*, referred to by the author following out the *Butterley* decision. The net result, as he understood it, was this, that where the instrument of severance—say, the colliery lease—contained specific power to work the minerals that were the subject of the demise, and it was well known both to the lessor and the lessee at the time of the letting of the lease that the minerals could not be worked according to the terms of the lease, and with due regard to the covenant to work contained in the lease, without producing the result of subsidence and consequent damage, the lessor must be considered to have by necessary implication granted to the lessee the right to cause that subsidence and that damage. Now, this law which culminated in the *Howley Park case* had come down to them, he would not say from medieval times, but, from the modern point of view, a long time ago. One of the leading cases was that of *The Great Western Railway* v. *Bennett*, which decided about 1866 that the 1845 Act did not confer upon the railway company any title to the minerals under the surface, and that the

owner was entitled to work them after having given notice, and that the only right of the railway company, in order to prevent damage to the railway, was to pay compensation by purchasing the minerals which were unworked. In the case of *Fletcher* v. *The Great Northern Railway Company*, decided shortly after *Bennett's case*, it was decided that a company purchasing under statutory powers did not have the right of the ordinary purchaser of the surface, the statute having created special rights governing the relationships of the parties. **Mr. H. M. Ingledew.**

In his paper the author said (page 189, para. 5): 'Up to the moment when the mine-owner desires to work his mines within the prescribed area, the undertakers have every right of subjacent and adjacent support; but from the receipt by them of notice of the intention of the mine-owner to work such mines, the common law right of support, as far as the minerals within the prescribed area are concerned, is taken away.' Now, with this he (Mr. Ingledew) quite agreed, but this was not the whole story, in that it did not include the question of the thirty days provided for in Section 78 of the 1845 Act. During the thirty days the common law right of support remained, inasmuch as the mine-owner could not work the minerals, but had to wait for thirty days in order to see whether the railway company intended to buy or not. The author went on to state (page 190, para. 3): 'The undertakers are not bound to any fixed period within which they *must* give a counter-notice.' This again was absolutely correct, and he should like to add that when once the counter-notice was given the railway company were in the unfortunate position of not being able to change their mind—they cannot withdraw it unless the mineral-owner consented.

A little lower down on the same page the author stated: 'Where compensation has been made for minerals left unworked, the minerals thus left do not become the property of the under-

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takers, but remain the property of the mine-owner. The only result is that neither the mine-owner nor the undertakers may remove such minerals. Where the mine-owner is at liberty to work the minerals within the prescribed area, as happens when the undertakers do not give counter-notice to treat for compensation within thirty days of notice of intention to work, working may only be done in a manner proper and necessary for the beneficial working of the minerals, and according to the usual manner of working such mines in the district where the same are situate; and if any damage or obstruction is occasioned to the railway or other works by improper working of such mines, such damage or obstruction must be forthwith repaired or removed, as the case may require, by the mine-owner, or in default thereof the undertakers may make good the damage and recover the expense occasioned thereby from the mine-owner.'

That again was novel to most of them, but he thought it was quite a correct exposition of the law. The only qualification, if qualification it was, was this—that, notwithstanding the mine-owner had been paid compensation for a certain block of minerals, he was still entitled to work those minerals—galleries and headings—for the purpose of working his undertaking as a whole. In reference to the *Howley Park case* Mr. Kenshole had spoken of the negotiations which took place between representatives of the Mining Association and the railway companies. The President and he (Mr. Ingledew) had the pleasure of meeting each other in those negotiations, but unfortunately he (the speaker) was on the other side of the fence, inasmuch as he was one of those representing the railway companies. (Laughter.) Now, the cardinal point which the two parties to those negotiations started from was this, that the effect of the *Howley Park* decision was to hinder the mine-owner from working minerals which might most usefully

and economically be worked in the public interest, and that therefore the decision might be considered to be contrary to the interests of the community as tending to sterilise the minerals affected. Mr. H. M. Ingledew.

Starting upon that assumption, the two parties tried to find a way by which the railway companies might have some reasonable protection within the purview of the *Howley Park* decision and the Mining Code of the 1845 Act, and at the same time allow the mineral-owner more freedom than he could get in a strict interpretation of the *Howley Park* decision to work his minerals. The general character of the position was this : under the 1845 Act and the Mining Code, the mineral-owner could go on working until he had approached to 40 yards of the railway company's boundary, a distance which, as had been pointed out, was based upon an assumed depth of about 200 yards, deep working at that time being unknown. Of course, they had now to deal with workings down to 1,000 yards, which meant that 40 yards was not very much protection for the railway company. On the other hand, the *Howley Park* decision did not define any distance, and the mineral-owner never knew, having regard to the faults which might exist in the ground, how far he could go, and perhaps there was a certain timidness on the part of the mine manager to incur responsibility in approaching the railway. It was provisionally agreed that when a mine-owner had approached to about half the depth of the seam, he should give notice to the railway company exactly in the same way as was provided with regard to the 40 yards area. If the railway company, after receiving that notice, wanted to buy the minerals, they could do so, but if they did not want to buy and said nothing, the mine-owner went on working and the railway company stood the racket. But if they agreed to purchase the minerals that were unworked, the negotiations were bound by the provisions of the 1845 Act and

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the 40 yards principle, and all the coal, which he might describe as the Howley Park coal, outside the 40 yards was bought at a price equal to one-third of that fixed for the coal within the 40 yards. But there was one important provision. When the railway company received notice from the mineral-owner they were entitled to say what pillar they required for the support of any of their works. As a matter of fact, in modern times the railway companies had not been in the habit of buying the coal, or notifying that they required a certain amount of pillar to be left, except in the case of an important viaduct, bridge, or tunnel, but the onus lay upon the railway company of saying what pillar they required, and having done this they had to pay for it on the basis which was agreed to.

That practice was reported to the Leslie Scott Commission, which commended it, but in the rush and worry of mining disputes and other matters, including—should he say—the German reparation question, it had not got any further. It seemed to be a commonsense method of dealing with a very difficult subject, because it safeguarded from unnecessary restrictions coal which ought to be worked.

He should like to refer to one or two matters with which the paper did not deal. There was, for instance, the question of the effect of the downward thrust, which was especially met with where a lease of the upper measures had been granted with a reservation of the lower measures to the landowner and the right to work them. In his own practice he had met with a case in which the upper measures had been bought outright, and the purchaser was entitled to complete freedom from obligation to support the surface, but the landowner, the vendor, was left free to work the underlying minerals without any obligation to support the upper measures which he had sold. But in that case it was agreed that the purchaser

of the upper measures had the right, correlative to his freedom from obligation to support the surface, also to freedom from any obligation in respect of injury to the lower measures by the effect of the downward thrust. **Mr. H. M. Ingledew.**

Then they got the case—it was a most common case —of a lease of the upper measures with a reservation of the lower measures coupled with the right to the landlord to sink through the upper measures for the purpose of winning the lower measures. Here, again, were difficulties arising in practice from the possibility of the landlord, exercising his reserved right, asking for something of the nature of a pit pillar for the support of his shaft down to the lower measures, while the lessee of the upper measures aimed at getting protection for his workings. It was not exactly a question of the law of support, but in respect of an influx of water it was this: that the lessee of the upper measures was entitled as a matter of principle—although he (Mr. Ingledew) was afraid questions of principle did not always go far when negotiating with landlords—to ask for, or at any rate he should receive, some kind of protection against the landlord by the putting in of a sufficient thickness of walling, say, in his shaft or insisting upon an effective pit pillar. This question of barriers—a more or less ancillary subject—was a question of lateral, not vertical, support; and the unfortunate working lessee was frequently compelled to provide what he considered extravagant barriers, consisting of coal for which he had paid the landlord, who, however, did not get the royalty on it, in addition to the barriers which he had to leave in the ordinary course for his own protection. As he had said, these were matters ancillary to the subject of the paper, but he thought they might be appropriately taken into consideration. (Applause.)

Mr. W. D. Wight said he hoped the legal gentlemen present **Mr. W. D. Wight.**

Mr. W. D. Wight.

would forgive him if he in any sense trespassed upon what might be considered their province, but as the paper came before an institute of engineers, perhaps they would allow him to put forward a few thoughts which had occurred to him from an engineer's point of view. (Hear, hear.) He need hardly say he had read the paper with great interest, because it had been his lot to be concerned in a number of cases where this matter of support was the point at issue. He did not suppose that any mining engineer would come to the conclusion that the paper would supply him with all the information necessary to guide him in meeting difficulties arising from subsidence. He should be careful against jumping to conclusions from the information given in Mr. Bowen's interesting communication.

Reference was made in the paper to subsidence produced by running silt and oozing pitch.

To give a supposititious case, he wondered what liability, if any, attached to the owner of land adjoining the sea coast if a stratum of pitch, which had been quiescent, commenced to flow to the sea, either by some necessary action of his or through natural causes, and thereby let down not only his own land but that of a neighbour, because of the pitch extending under both properties. Would the coast land proprietor be responsible to the more remote owner for not stopping the outflow ? He did not ask this question expecting an answer from the learned author of the paper but merely to indicate one difficulty that might arise in connection with the law of support. He had heard very much the same point argued with great ability in cases where water had been allowed to accumulate in underground workings, and he could assure members that there was a great deal to be said on this branch of the subject.

The question of the effect upon an upper seam of working lower measures was also very interesting, and as far as he

could gather, the law was not definite upon it; but to the engineer's mind the desirability of including all seams in one letting was manifest. **Mr. W. D. Wight.**

The practice of letting a number of lower seams to different parties was most objectionable. He had even known it suggested that a seam lying between others should be let to a different lessee—an arrangement obviously undesirable.

The author stated that the right of support for buildings might be acquired by prescription where it had been enjoyed from time immemorial. This reminded him of an occasion upon which he gave evidence in an action for subsidence when he said it had been common knowledge 'from time immemorial' that the extraction of minerals resulted in the letting down of the surface, and counsel twitted him as to his experience extending over so long a period. (Laughter.) On a subsequent occasion, however, when the same counsel jocularly recalled this part of his previous evidence, he (Mr. Wight) turned the laugh (having meanwhile consulted a dictionary) by stating that 'time immemorial' in a legal sense commenced from the reign of King Richard II. (Laughter.) He might add that the judge decided it was not common knowledge at the time of the granting of the surface lease and that damage had been done to the buildings by subsidence due to the extraction of minerals, although the knowledge might have been 'common' to mining engineers and lawyers. Another nice point was that involved in the case of *Dugdale* v. *Robertson*, cited by Mr. Bowen. Here it was held that in addition to working being prohibited underneath a certain area of four acres, the land and buildings within that area were entitled under common law to support. Now, all mining engineers knew that the supporting area increased with the depth of the workings, but there was diversity of opinion as to the additional area required. The difficult problem for

Mr. W. D. Wight.

the mineral lessee was to avoid a breach of covenant where it is stipulated that all coal has to be gotten, or transgressing the common law by withdrawal of the necessary support. It pointed to the importance of exercising extreme caution in entering into a mineral lease. Draft leases were too often accepted as a matter of form, and sometimes they were forced upon lessees by implacable landowners' representatives, who insisted upon old forms without having regard to modern methods of working and recent legal decisions. With reference to the *Howley Park case*, it had occurred to him since that decision had been given that it would be quite possible under the old interpretation of the law to work under that railway. That was to say, they were allowed 40 yards on each side of the railway and say 30 yards of the railway itself, or a width of 110 yards. What would be the position, provided they kept strictly under the railway and worked a stretch 110 yards, leaving the required coal for support on each side ? If they did this, it was within the bounds of possibility that subsidence of the railway would take place, while they had left the support stipulated by the law. Who would be liable ? Would the lessee be responsible for damaging the railway by working under the old understanding of the law when only extracting the coal within that 110 yards ?

The President.

The President said he felt some diffidence in putting forward points of a legal aspect in the presence of legal gentlemen, especially as they touched upon the law not so much as it was at present but what he was going to suggest the law ought to be in some cases. The first point was the basic point as to the right which the surface owner enjoyed of absolute support. Unless it was otherwise provided by covenant, the mineral lessee must substitute either absolute artificial support or leave sufficient of the original mineral to give absolute support. Then they came up against the problem whether

The President. this was practicable. For his own part, he had never subscribed entirely to the law of inevitable subsidence. He believed that in cases where they had flat seams, with good roofs and shallow depths, it was perfectly possible to leave enough of the original mineral to support the surface. It was, however, agreed that with longwall working, and leaving pillars where the roofs were bad and the depths great, it was impossible to maintain the surface. If pillars were left in such conditions, they would naturally in time grind and shrink, and the roof would fall down, and there would be subsidence. Some maintained that, with the best form of stowage, damage by subsidence could be reduced to a very small amount, and he concurred ; but if the surface was lowered even an inch or two, the lessee was liable to an injunction. This raised the question whether it was in the best interests of the community that a single individual should have the right to prevent the working of large areas of coal the value of which had no relation to the amount of surface damage. This point came before the Leslie Scott Committee, who came to the conclusion it was not in the interests of the community that such a power should be vested in a private individual which if exercised led to the sterilisation of coal, but suggested that the proper way to deal with the question was for an independent tribunal to investigate the circumstances and decide whether it was advisable in the national interest that the coal should be worked or the surface supported. At the same time, the Committee quite realised it would be unfair to the surface owner to take away the absolute right which he enjoyed without ensuring that he was compensated, and the only way they could see of providing for that was the formation of an Insurance Fund to which the mineral worker should contribute, and the sufficiency of which should be guaranteed by the State in the early years of the fund's existence, because until information and data

The President. were available it might not be possible to work out a scheme on proper lines.

Looking at it from the point of view of the general community, he thought that this was a possible way in which the law might be improved. The next point he had to deal with was rather more in the nature of criticism of the method as he understood it of arriving at judgments under the law of inevitable subsidence. The author of the paper referred to the question when he said : 'Whether such evidence is available will depend on the date of the instrument, but the law of inevitable subsidence has been known to mining engineers for many years, and this principle probably applies to most mining instruments.' It would seem that a lessee who was working under an old lease would be penalised as compared with a lessee working under a modern instrument, not because the law of inevitable subsidence, which was said to be true to-day, was not true sixty years ago, but because dead men could not be produced to say what they knew about it. In other words, evidence could not be produced to show that the people who entered into the instrument at that date knew of the law of inevitable subsidence. In his view the old mining men were very able practical men, and what they did not know about working coal, from the practical standpoint, was very small. It was probable they could not work out the law of subsidence scientifically, and he did not know that at the present day we were very expert at that either, but the former generation of mining engineers probably knew as much as was known to-day of the effect on the surface of working coal. But, as he had said, they could not produce the direct evidence of these older engineers to show exactly what they knew in their day. The only other point he would refer to had been very adequately dealt with by Mr. Ingledew ; namely, the *Howley Park* decision. He had always felt that the mineral

worker had some grievance against the law on that question, and he was rather amused at the way in which Mr. Bowen had put it in his paper. Mr. Bowen had, perhaps, rather camouflaged it because he said that before that decision was pronounced the point was obscure, but the other legal gentlemen who had addressed the meeting had put it in the way that he (the President) would have liked to put it; namely, that neither statutory undertaking nor the mineral worker nor the lawyer believed the law to be what it was stated to be until the *Howley Park* decision was given. He never could understand why the legislature drafted the railway clauses if it had intended that the statutory undertaking should have support without paying for it. It seemed to him that the railway companies would be amply protected under the common law of support, and that it was quite unnecessary to have any railway clauses unless it had been the intention to do something different from the common law of support. It had always seemed to him that what was probably in the minds of the people who drafted the Railway Clauses Act was something to this effect: 'We are giving these people the right to compulsorily acquire other people's property for the purpose of making profit and we must see that they pay compensation for anything they take or use'; but he did not doubt that if deep mining had been engaged in when those clauses were drafted, the 40 yards stipulation would have been immensely increased. He quite agreed with what Mr. Ingledew had said as to the negotiations that took place after the *Howley Park* decision, and as to the reason for the compromise which was suggested. In his opinion, it was a compromise which might very well be carried into effect with advantage to all parties. **The President.**

Replying on the discussion,

Mr. DAVID BOWEN said he was much obliged for the kind **Mr. David Bowen.**

Mr. David Bowen.

remarks that had been made upon the paper. As he came down to Cardiff he recalled that about a year ago Mr. Ingledew read an excellent paper to that Institute upon a subject closely allied to that which was now under consideration, namely, on Mining Leases. He had derived great pleasure from a perusal of such a paper written by one whose legal practice was particularly concerned with colliery leases in South Wales. The remarks, too, on the present occasion, of Mr. Kenshole and of Mr. Ingledew were full of information, and it was somewhat difficult to discuss on the spur of the moment some of the points those gentlemen had commented upon. But, speaking broadly, the questions raised in the discussion were concerned either with the general common law right of support or with rights under the Mining Code, and it would be convenient if these were dealt with irrespective of the order in which they arose in the discussion.

The President had remarked that if the surface were lowered an inch or so then an action would lie. In the absence of particular circumstances it might be going too far to say that subsidence amounting to an inch or so would *per se* found an action. To such a case the legal maxim *De minimis non curat lex* might apply. The damage must be substantial. and it is quite conceivable that the general subsidence of one inch or so over a large area of ground unincumbered by buildings would cause no pecuniary loss at all to the surface owner. There must be something more than that in the case.

The case of liability under a covenant in a lease to get all the coal demised is of frequent occurrence. In the absence of other conditions, affecting the performance of such a covenant, the lessee is liable in damages for breach of covenant if he does not perform it, and if as a result of its performance he lets down the surface he is liable for damages owing to subsidence.

As to the problem propounded by Mr. Wight in regard

to a stratum of pitch, the case is governed more or less by the decision in *Trinidad Asphalt Co.* v. *Ambard* (1899), App. Cas. 594, and by the case of *Jordeson* v. *Sutton, etc., Gas Co.* (1899), 2 Ch. 217, and by the general principle of common law as to lateral support. If the pitch flows to the sea solely through natural causes the owner of the land adjoining the seashore is under no obligation to prevent the flow, nor is he liable in damages to his neighbour because of any subsidence of his neighbour's land owing to the motion of the pitch. It is different if the motion of the pitch is caused through the act of such owner, though it is a necessary act. The case of pitch is distinguished from the case of water percolating underground. A man may drain his own land of water without any liability in damages if damage thereby results to his neighbour's land —provided he was under no express or implied obligation to his neighbours not to do any act that would bring about such damage. There is no right of property in water percolating underground in an unknown channel. But there is a right of property in an underground stratum of pitch, so that the first owner is liable to his neighbour for the value of the pitch flowing on to his land from that of his neighbour if he appropriates it, and for damages in respect of subsidence caused by the withdrawal of lateral support and which caused the pitch to flow. **Mr. David Bowen.**

The difficulties which may arise when the various seams under a particular area are leased to several parties are, as both Mr. Ingledew and Mr. Wight have pointed out, real difficulties, and in drafting leases in such cases it is necessary to be exceedingly careful. It so happens that he (the author) had had occasion to draft two such leases in the course of the few days immediately preceding this meeting. The possible case of a downward thrust propounded by Mr. Ingledew was a contingency one had to consider in such cases, and he was

Mr. David Bowen.

glad to say he had borne this in mind in the leases referred to. The President had remarked upon the difficulty of adducing evidence before the Court of living witnesses whose memories could support the written testimony of old documents. The question also arose as to the practice of mining in old times and the state of knowledge of mining engineers in those day, as to the consequences—from the point of view of subsidence—of such methods of mining. These are questions of evidence, and very often the question arises as to the relevancy of such evidence and particularly as to its cogency. An interesting case in point is that of *The Consett Industrial, etc., Society, Ltd.* v. *The Consett Iron Co.*, in which judgment was given on April 22nd last. It was contended by the defendants in that case that it was the practice in 1773 to take out 75 per cent. of the coal, where the method of working was by bord and pillar, and that it was commercially impracticable to work in such a way as not to let down the surface. Whether the question of commercial practicability is a relevant question in such a case or not, the learned judge at any rate on the evidence found that in 1773, as it is at the present day, it was commercially practicable to work without letting down the surface. If there were two methods of mining in vogue in a particular district, one of which caused subsidence while the other did not, it would be impossible to say that the parties must have contemplated the system which caused subsidence. In this particular case, a number of ancient leases—one as far back as the reign of Queen Elizabeth—were in evidence. A large number of old miners' reports and plans, lent by the Society of Antiquaries at Newcastle-on-Tyne, were also in evidence. The works of Mathias Dunn on the Coal Trade, and reports by Mr. Nicholas Wood, cited in Bulman and Redmayne's 'Colliery Working and Management,' were quoted and

discussed. These documents, plans, and reports were all so ancient that it was only possible to obtain the opinions of expert witnesses upon them, and as to what inferences they could draw as to the practice of mining in those times. Although the opinions of these experts were conflicting upon these points, the learned judge held that the practice in 1773 in the Lanchester District of Durham was to leave four-ninths of the coal in pillars, and that this resulted in no subsidence, and therefore a power to let down the surface was not implied. With regard to the Mining Code and the *Howley Park case*, they had heard a great deal about it from Mr. Kenshole, Mr. Ingledew, and the President, who was a member of the Leslie Scott Committee, and he (Mr. Bowen) did not think he need say much upon it. As to the question of support outside the 40 yards area, the point had been suggested as to the position of the mineral worker if the Mining Code had not been passed. In that event the position of the railway company would have been exactly the same as that of any other surface owner where the natural right of support was not taken away, and the mineral worker would have been entitled to work under the railway provided he did not cause any damage to the surface. The liability to pay compensation to the surface owner, however, might not prevent his exercising his right to get his minerals; and the Legislature, when it passed the Mining Code, had in view, at any rate, that the mere obligation of supporting the surface was not in itself sufficient, that something else was required, namely, actual prohibition of working the minerals underneath a railway if the railway company chose to exercise its statutory right to require minerals to be left provided it paid compensation. Mr. Wight had given a supposititious case as to minerals being worked at such a depth as to require 110 yards of support outside the 40 yards,

Mr. David Bowen.

Mr. David Bowen.

and had asked what would happen if within that 110 yards the mineral-owner worked his minerals. Under the *Howley Park* decision the railway company would still be entitled to the common law right of support outside the 40 yards limit. No limit was laid down outside the 40 yards. If the railway was injured by working of minerals outside the 40 yards—if that was the distance in the absence of any agreement to the contrary — the railway company was entitled to claim damages for any injury done to the railway.

The President.

The President said he understood Mr. Wight's point was, if the 110 yards which absolutely underlay the railway was worked and the lateral support was left.

Mr. Wight.

Mr. Wight: Yes, sir.

Mr. David Bowen.

Mr. Bowen said that under the common law the railway company had the right to vertical and lateral support. The Mining Code had the effect of taking away the common law support as regards minerals under the railway and within the 40 yards limit (from the time notice was given by the mineral-owner of his intention to work such minerals), and substituted for it a statutory right to have the minerals left unworked provided the railway company paid compensation for such minerals.

Mr. Wight.

Mr. Wight: Suppose they fail to serve notice?

Mr. David Bowen.

Mr. Bowen: If you have given notice of your intention to work and they fail to serve counter-notice, you may proceed to work the minerals provided you work in the manner laid down by the statute. Continuing, the speaker said in his paper he stated: 'Where the mine-owner is at liberty to work the minerals within the prescribed area, as happens when the undertakers do not give counter-notice to treat for compensation within 30 days of notice of intention to work, working may only be done in a manner proper and necessary for the beneficial working of the minerals, and according to the usual

Mr. David Bowen.

manner of working such mines in the district where the same are situate; and if any damage or obstruction is occasioned to the railway or other works by improper working of such mines, such damage or obstruction must be forthwith repaired or removed, as the case may require, by the mine-owner, or in default thereof the undertakers may make good the damage and recover the expense occasioned thereby from the mine-owner.' So that as long as the mine-owner worked in a skilful and proper manner within the description laid down by statute there was nothing to prevent him working his minerals within that specified area except that he was liable for any damage which might ensue. Reference had been made to the case of *The Great Western Railway Co.* v. *Bennett.* This was very fully considered in the course of the Howley Park action, and reading through the latter proceedings the other day he gathered that the view of the majority of the court was that, as regarded minerals outside the 40 yards, the case of *The G. W. R. Co.* v. *Bennett* was not at all decisive, and therefore did not govern the *Howley Park* litigation. This to a certain extent explained the obscurity in which mining engineers were left as to what would happen if they worked outside the 40 yards limit. Part of the land affected in the case of *The G. W. R. Co.* v. *Bennett* certainly was outside the 40 yards limit, but not sufficient stress was laid upon that point when the case was before the Court, if he remembered rightly. The argument of counsel was not directed to it and the Court did not take it into consideration. Concluding, Mr. Bowen said it had afforded him great pleasure to prepare the paper and submit it to the Institute. (Applause.)

The President.

The President, in moving a cordial vote of thanks to Mr. Bowen, said they were much indebted to that gentleman for his excellent paper, which had evoked a useful and valuable discussion.

Resumed discussion on Mr. R. C. Morgan's paper, 'Causes of Subsidences and the Best Safeguards for their Prevention,' was deferred, as was also the opening of a discussion on the paper by Mr. Robert James, Wh.Sc., on 'Powdered Fuel.'

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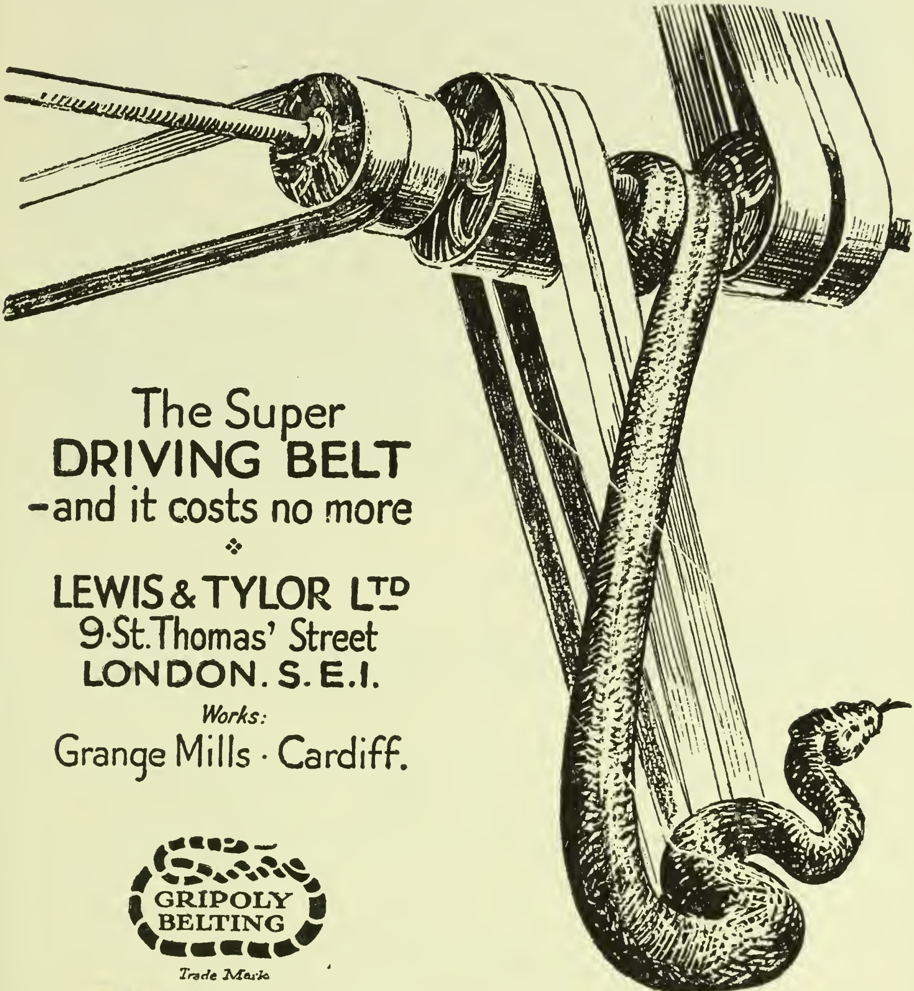

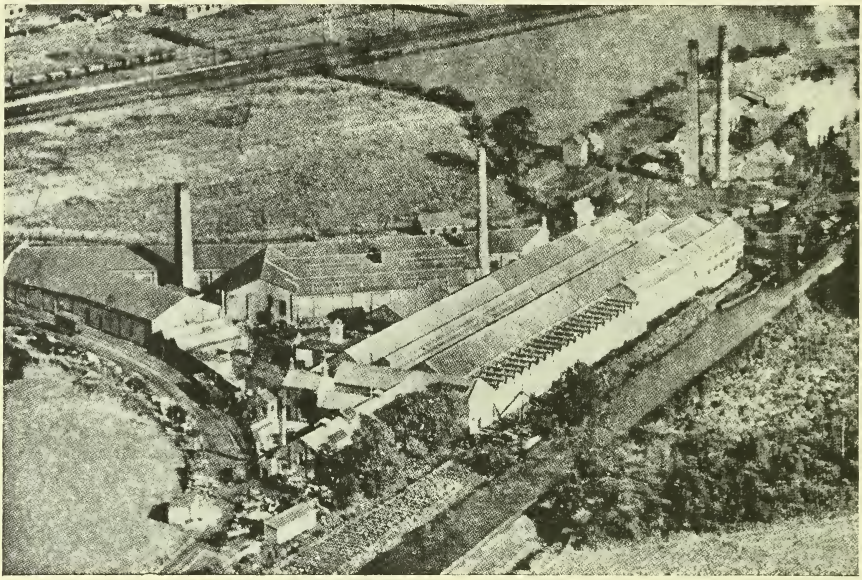

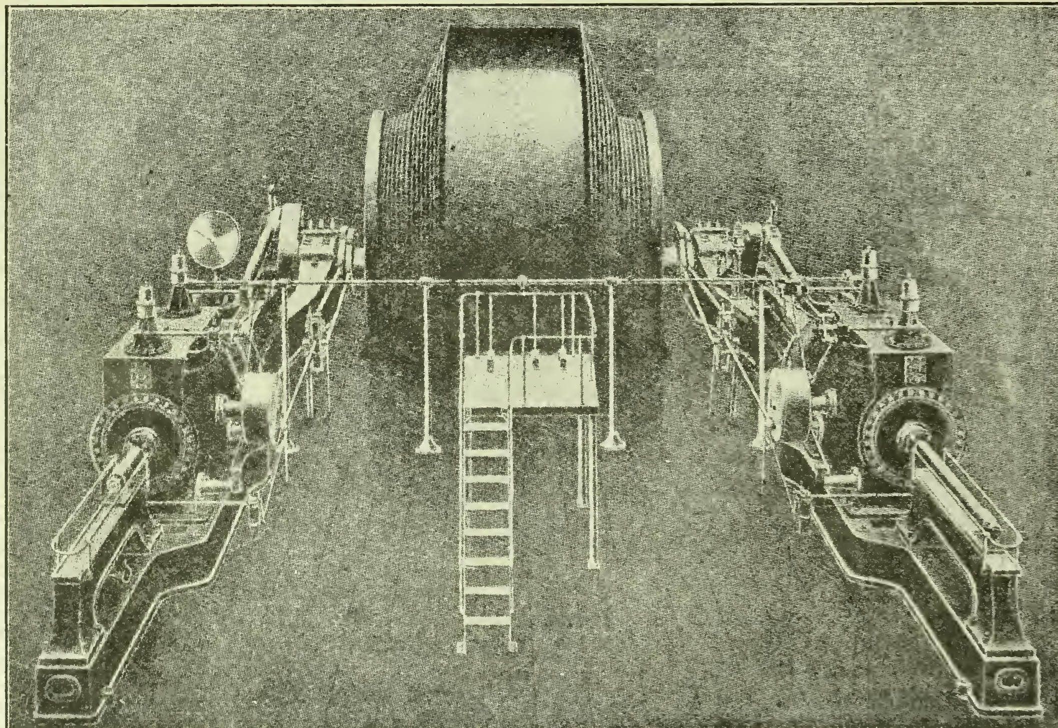

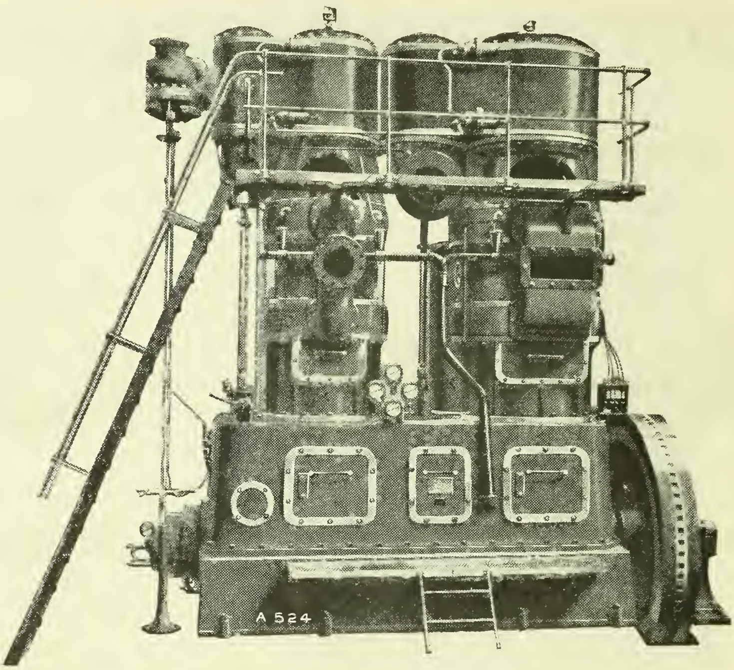

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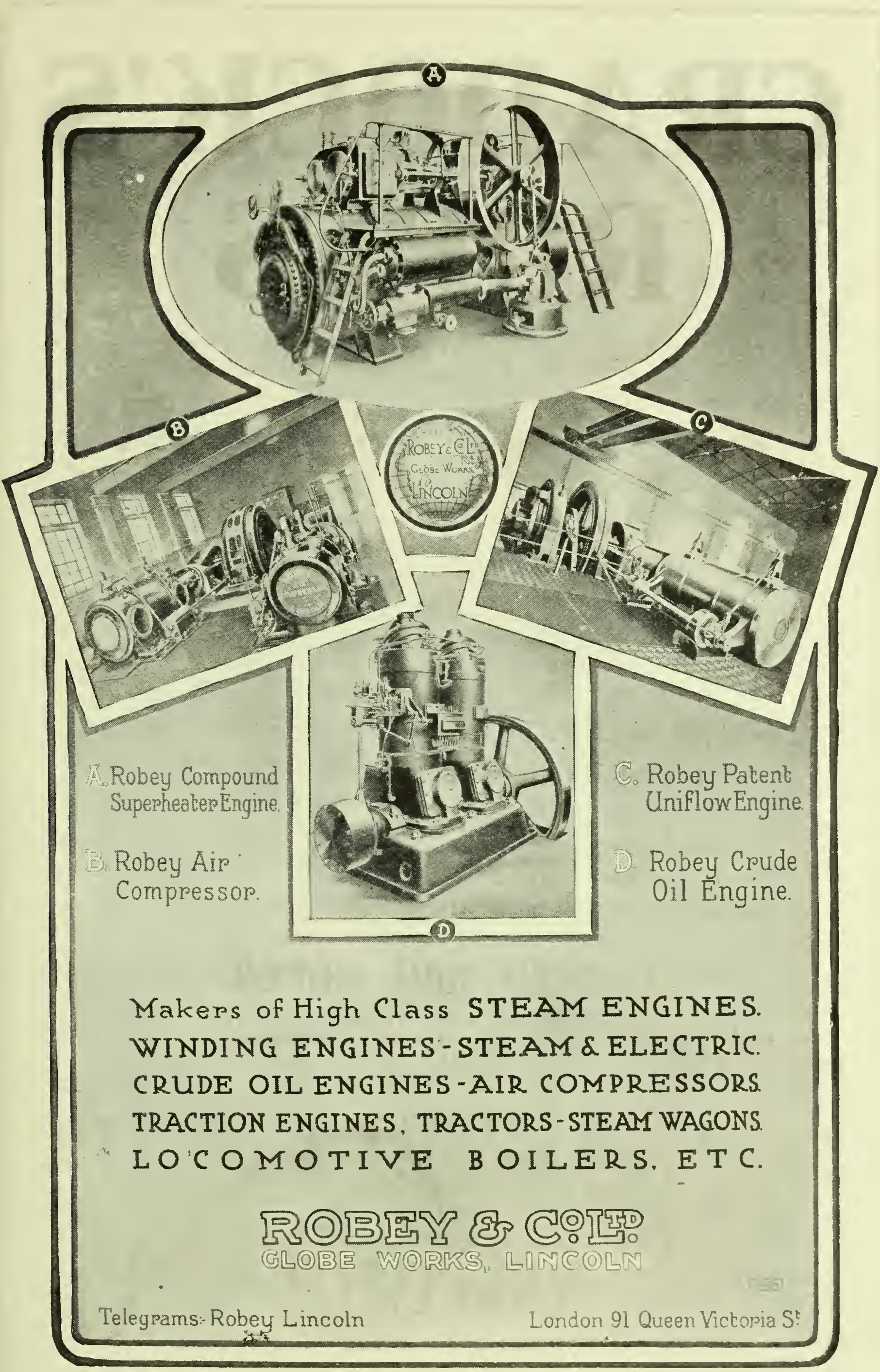
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Secretary.

PRICE, MARTIN	Institute Buildings, Park Place, Cardiff.

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Treasurer.

THE MANAGER, LLOYDS BANK, LIMITED	Cardiff.

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HOLDERS OF

THE PRESIDENT'S GOLD MEDAL AND CERTIFICATE.

Established in 1904, and to be awarded—in the discretion of the Council—for the best Papers read in each Presidential term.

1904.

THE FIRST GOLD MEDAL

WAS AWARDED TO

Mr. HENRY K. JORDAN, F.G.S.

PAPER, "THE SOUTH TROUGH OF THE COAL FIELD, EAST GLAMORGAN.

1908.

THE GOLD MEDAL

WAS AWARDED TO

Mr. EDMUND MILLS HANN, M.Inst.C.E.

PAPER, "A RECENT PLANT FOR THE UTILISATION OF SMALL COAL."

1910.

THE GOLD MEDAL

WAS AWARDED TO

Mr. HUGH BRAMWELL

PAPER "RE-SINKING AND RE-EQUIPPING THE GREAT WESTERN COLLIERY COMPANY'S MARITIME PIT."

1912.

THE GOLD MEDAL

WAS AWARDED TO

Mr. GEORGE G. HANN.

PAPER, "SINKING AND EQUIPPING THE PENALLTA COLLIERY."

THE INSTITUTE GOLD MEDAL.

In 1917 by Resolution of Council the name of the Medal, "The President's Gold Medal," was changed to that of "The Institute Gold Medal."

1917.

THE GOLD MEDAL

WAS AWARDED TO

Mr. GEORGE DOUGLAS BUDGE.

PAPER, "STONE DUSTING IN STEAM COAL COLLIERIES."

LEWIS PRIZE.

Founded in 1895 by the late LORD MERTHYR of SENGHENYDD (Past-President), K.C.V.O., M.Inst.C.E., for the best Papers on subjects connected with Practical Mining and Practical Engineering, including Metallurgy.

1898. A First Prize was awarded to Mr. E. H. Thomas for his Paper on "Haulage," and a Second Prize to Mr. G. E. J. McMurtrie for his Paper on "Sinking."

1900. A First Prize was awarded to Mr. S. A. Everett, and a Second Prize to Mr. E. H. Thomas, for Papers on "Colliery Surface Arrangements."

1901. A Second Prize was awarded to Mr. Ralph Hawtrey, a Student, for his Paper "The Best and Most Economical System of Working Seams of Coal of Moderate Inclination in South Wales."

1904. A First Prize was awarded to Mr. H. D. B. How, A.M.I.E.E., for his Paper "Coal Winding Machinery."

1905. A First Prize was awarded to Mr. W. Waplington for his Paper "Description and Design of the Best Arrangements of Equipment of the Bottom, with a Radius of 400 yards, of a Pair of Pits to be Upcast and Downcast Respectively."

1906. A Second Prize was awarded to Mr. George Roblings for his Paper "Separation (Sizing) and Washing of Coal."

1907. A First Prize was awarded to Mr. Daniel Davies, and a Second Prize to Mr. Gath J. Fisher, for their Papers on "Pumping and Drainage," and also on "Sinking Shafts."

1908. A First Prize was awarded to Mr. H. A. Staples, a Second Prize to Mr. George Roblings, and a Third Special Prize to Mr. M. D. Williams, for their Papers "As to the Best Methods of Working Seams of Coal in Steep Measures."

1909. A First Prize was awarded to Mr. William Trimmer, and a Second Prize to Mr. C. W. Jordan, A.M.I.Mech.E., for their Papers on "General Lay-out and Equipment of a Complete Set of Engineering Shops for a Modern Colliery with an Output of about 2,000 tons per day."

1910. A First Prize was awarded to Mr. George Roblings, and a Second Prize to Mr. Noah T. Williams, for their Papers on "Washing and Sorting of Small Coal."

1913. Special Prize awarded Mr. Will Gregson for his Paper "The Most Approved Methods of Hauling the Coal from the Working Faces to the Pit Bottom."

1914. Special Prizes awarded Messrs. J. Williams and S. R. Cound for their Papers on "How to Improve Welsh Tinplate Rolling-mill Practice."

1918. A First Prize was awarded to Mr. W. T. Lane, and a Second to Mr. W. H. Casmey, for their Papers on "Fuel Economy in Power Production (or Utilisation of Waste Heat)."

1920. A First Prize was awarded to Mr. R. C. Morgan for his Paper on "Causes of Subsidences and the best Safeguards for their Prevention."

1921. Subject selected: "Improved Mechanical Methods for bringing Coal from long distances in view of the necessity for Increased Output." 1st Prize £20, 2nd £10.

INSTITUTE SCHOLARSHIP IN ENGINEERING.

Granted by the Council in 1904, and tenable for three years at the University College of South Wales and Monmouthshire.

1904.—An EXHIBITION of £60, awarded to Mr. Ernest Clarke Stroud, Chatham.

1905-08.—A SCHOLARSHIP of £70 per annum, awarded to Mr. E.C.Stroud.

1908-11.—A SCHOLARSHIP of £70 per annum, awarded to Mr. Ivor Richard Cox, Cardiff.

1912.—An EXHIBITION of £60, awarded to Mr. Victor John French, Chatham.

1912-15.—A SCHOLARSHIP of £70 per annum, awarded to Mr. Victor John French.

1915-18.—A SCHOLARSHIP of £70 per annum, awarded to Mr. E. W. H. Knight, Devonport,

NOTE.—Mr. Knight was unable to take up the Scholarship he had won, and an honorarium of £10 was granted him by the Council, also a Certificate to the effect that he had won the Scholarship.

1919-21.—An EXHIBITION of £13 (plus a bonus of £15) per annum, awarded to Mr. E. G. Davies, Cardiff. (Won in 1915.)

1919-21.—A SCHOLARSHIP of £70 per annum, plus a bonus of £15 per annum, awarded to Mr. Myrddin David, County School, Porth, and

1919-20.—An EXHIBITION of £30 per annum for two years, awarded to Mr. J. Selwyn Caswell, Ebbw Vale.

NOTICES.

The Editor of these Proceedings is directed to make it known that the Authors alone are responsible for the facts and opinions contained in their respective Papers, and the individual speakers for their statements made in discussion.

He is also directed to state that the COPYRIGHT of all the Papers and Discussions published in these Proceedings is the exclusive property of the Institute, and reproduction of any of the Papers is prohibited unless in each case the consent of the Council has been previously obtained.

PROCEEDINGS.

Back Numbers of the Proceedings have now been bound, from Vol. I. inclusive, in Volumes, in strong Duro-Flexile Cloth, and may be obtained from the Secretary at £1. 1*s*. per volume, or separate back numbers can be had at the various prices marked on the covers.

CHANGE OF RESIDENCE.

The Secretary would be obliged by Members notifying to him any alteration in their addresses at the earliest date.

INSTITUTE BUILDING.

The Institute, Park Place, Cardiff, is open for the use of Members on Week-days from 10 a.m. to 5 p.m.

The New Library is now open for the use of Members, and the technical journals and other periodicals will be found on the tables in that room, instead of in the Council Chamber.

SPENCE THOMAS SCHOLARSHIP.

(Founded in 1918 by Mr. H. Spence Thomas for the encouragement of the Members of the Associations of Students of the Institute.)

The interest on £1,000 5 per cent. War Loan Stock shall be devoted to the Scholarship.

The Holder of the Scholarship must be a Member of one of the Students' Associations of the Institute, and must be a Student at one of the Colleges, Schools, or Institutions recognised as suitable by the Council of the Institute.

The Council of the Institute shall award the Scholarship upon Reports presented for its consideration by the Heads of any of the above Colleges, Schools, or Institutions, on the completion of one year's study by any student.

The College, School, or Institution shall present an annual report to the Council on the work and progress of the Scholar to whom the Scholarship shall have been awarded, and the Council retains the right of withholding or cancelling the Scholarship, if in its opinion the progress of the Scholar is unsatisfactory.

In the award of the Scholarship the professional knowledge and practical experience of the candidate shall be taken into consideration.

No candidate will be elected to the Scholarship until he has satisfied the Council that his physical condition is satisfactory.

The Scholarship shall be awarded for a term of one, two, or more years in the discretion of the Council. The Scholar to briefly report at the end of each year upon the work accomplished.

The Council reserves the right to withhold the Scholarship if no candidate of sufficient merit presents himself.

1919–1921. The Spence Thomas Scholarship of £50 per annum was awarded to Mr. William John Gilbert, Nantyglo, for a period of three years, tenable at the School of Mines, Treforest.

ADVERTISEMENTS.

CONTENTS.

No. 3. Volume XXXVII., issued July 7th, 1921, price 5s.

PROCEEDINGS.

An Ordinary General Meeting of the Institute was held at the Royal Metal Exchange, Swansea, on Tuesday, May 31, 1921.

The chair was taken by the President, Mr. W. Forster Brown, M.Inst.C.E.

The minutes of the preceding Special General Meeting held at Cardiff on April 28, 1921, were read and confirmed.

Election of Members.

The following candidates for admission to the Institute were declared to be duly elected:

As Members.

Arnold, Jonah	Neath.
Bassett, T. B.	Llangennech, Carm.
Davis, J. D. D.	Swansea.
Davies, R. B.	Gilfach Goch, Glam.
Davies, W. R.	Melingriffith, Cardiff.
Evans, H. H.	Cilfynydd, Glam.
Evans, John	Pontypridd.
Ferguson, Daniel	Ogmore Vale.
Nettleton, Stanley	Wimbledon.
Plevin, P. J.	Penarth.
Schenk, H. G.	Landore.

As Associate Member.

Harris, R. D.	Seven Sisters, Glam.

As Associates.

Blewett, T. C.	Glynfach, Porth, Glam.
David, W. L.	Stoke-on-Trent.
Evans, T. J.	Garnant, Carm.
John, W. H.	Porth, Glam.

Swansea University College Engineering Students.

The President. The President said before entering upon the agenda of the meeting he might state that the Council of the Institute had had under consideration that day the question of the formation of an Association of engineering students at the University College of Swansea to be affiliated to the Institute on the same lines as the associations which had been established in the eastern part of Glamorgan and in Monmouthshire. Principal Sibly was present with them that day, and he would call upon him to express his views upon the matter.

Principal Sibly. Principal Sibly said he had some knowledge of the Associations of Engineering Students at the University College, Cardiff, and at the School of Mines, Treforest. The proposal to form a similar association at the University College, Swansea, had not yet come before his Council, but he felt confident they would encourage it when it was brought under their notice. With his colleague, Professor Bacon, he should welcome most cordially the proposed link between their engineering students and the South Wales Institute of Engineers.

As the members were aware, the University College of Swansea was a new institution, and at the outset the Association of Engineering Students would not be a large one,

but he felt sure that what they might lack in numbers they would make up in keen and sustained interest. Principal Sibly.

The PRESIDENT said the Institute would cordially welcome the proposed association. The Students' Associations at University College, Cardiff, and at the School of Mines at Treforest and Crumlin were a great success as far as they had gone, and he had no doubt the Institute would be equally proud of the Swansea Association when it was formed. The President.

Powered Fuel.

By ROBERT JAMES, WH.SC.

(FOR PAPER *vide* PROCEEDINGS, VOL. XXXVII., NO. 1, p. 75, AND FOR DISCUSSION THEREON *vide* PROCEEDINGS, VOL. XXXVII., NO. 2, p. 157.

Discussion was resumed on this paper.

Professor FREDERIC BACON said they were indebted to Mr. James for having submitted this paper to draw their attention to the possibilities of powdered fuel. If America with its cheap coal, vast oilfields, and considerable water-power resources, found it worth while to burn over ten million tons per annum of its coal in a powdered form, it was surely high time they in Britain started looking into the proposition for themselves. With the exception of Mr. Leonard Harvey's report to the Department of Scientific and Industrial Research, which dealt exclusively with American practice, and was now three years old, Mr. James's paper was the only contribution he had seen treating the subject of pulverised fuel from a broad and unbiassed standpoint. He had only one thing to say by way of criticism, and this was a small matter. The title of the paper was a little too wide for its contents. The author called it 'Powdered Fuel,' but the paper contained no reference to powdered peat or lignite; and in regard to Professor Frederic Bacon.

Professor Frederic Bacon.

the application of the fuel, only four of the paper's thirty-five pages were devoted to its suitability for metallurgical purposes. Perhaps a more accurate title would be 'Powdered Coal in its Application to Steam Raising.' The paper bore evidence of having been carefully prepared, and Mr. James described the rival systems with such studied impartiality that it was rather difficult to discern his personal preferences or opinions. They could not expect industrial firms to be eager to embark upon capital expenditure upon lines that had not been well explored unless there was a reasonable prospect of substantial raising.

What did they find ? If they added 20 per cent. to the heat efficiency of the boilers by cutting down the stack losses arising from excess air, they would certainly be doing well; but if, as seems needs must be, they could hope to get coal again at some such price as 30*s.* per ton, the pulverising costs at Mr. James's estimate of 7*s.* 6*d.* per ton are straightaway raising the cost of the fuel 25 per cent. to secure a saving of 20 per cent. Hence, if it is merely a case of steaming at constant load, the proposition looks very like spending 25*s.* to save a sovereign. It may be the right thing to do from the point of view of coal conservation, but it was not what appealed to the business mind.

On fluctuating and intermittent loads, firing with powdered fuel provides for easy adjustment and ability to extinguish the fire instantly. It therefore became possible to save the fuel at present used for banking boilers at nights and week ends; but what effect would such procedure have on boiler maintenance ? He was afraid many Lancashire boilers would get racked to pieces in no time if stokers had it in their power to let things cool down over night and then turn on fierce powdered fuel burners suddenly the next morning to bring up the steam pressure.

Professor Frederic Bacon.

Again, is it not largely a fallacy to think that because you have turned out your fire, you have thereby eliminated banking losses? Your boiler remains hot and radiation losses continue all the night long and all Sunday, and the heat lost in this way has got to be made good again before you can get back to normal steaming conditions.

He was not losing sight of the fact that in a plant of some size there would be a substantial saving in labour as compared with hand firing; but there is formidable capital expenditure necessary to obtain that saving. The crushing, drying, and pulverising plant require a building of some size, and the transportation system—no matter which be adopted—also seemed to demand much valuable space. What is far more serious, the reliability and safety of the whole plant seemed somewhat questionable. As powdered coal could only stand storage for a few hours, trouble in the mill house would be quickly followed by a general shut down, and there was always the danger of coal dust explosion lurking in the background.

Of the three systems of transportation, viz. by screw conveyor, by compressed air, and by suspension in a current of air, the last-named was the nearest approach to gas or oil distribution; but it seemed to be the most liable to explosion of the three. He would like to ask whether better safety could not be secured by circulating the coal dust suspended in a closed circuit of inert gas; also whether the idea of using coal dust to enrich a lean gaseous fuel had ever been tried.

It occurred to him as possible that by injecting powdered coal in suspension with blast furnace or producer gas it might be possible to make powdered coke or anthracite burn without the admixture of bituminous coal dust.

In view of the fact that powdered fuel systems were intended to make it possible to burn coal of high ash content, though the ash did in fact prove to be decidedly troublesome, it

Professor Frederic Bacon.

surprised him to find that the mill house equipment did not appear to include any appliance whose function it was to separate the powdered ash from the powdered combustible before passing it on to the burners.

Would it not often be possible to remove a good deal of the powdered shale and other incombustible of high density by suitably combining screens for sizing and air separation for leaving the denser incombustible particles behind ?

With the exception of the arrangement for locomotives he thought that all the transportation systems were expensive, awkward, and somewhat futile attempts to make a powder flow like a liquid. For adjusting the flow, for instance, a screw feed driven by a variable speed motor was really a horribly complicated, delicate, and unreliable device compared with a simple plug cock or screw-down valve.

What appeared to have greater potentialities for using coal dust or anthracite duff was colloidal fuel, which was just mentioned in the paper. Here they had carbon particles held in a form which was truly liquid, using, of course, a good deal of oil as well, and obtaining in full measure the advantage of liquid control. The author touched upon the speculative possibility of using powdered coal fuel in the internal combustion cylinder, and said the prospect was hopeful. He would like to know the grounds of Mr. James's optimism. It was well known that Dr. Diesel, in his original experiments, tried to make his engine work by powdered coal fuel, but did not make headway until he went over to oil. The Diesel engine would work on a great variety of oils, but it was not reliable unless objectionable materials such as ash and sulphur were present only in extremely minute traces. If, as is commonly specified, ash in oil suitable for the Diesel engine must not exceed one-tenth per cent., it did not promise favourably for the burning of powdered coal in the internal com-

Professor Frederic Bacon.

bustion cylinder. Another difficulty was that while coal dust in air was too prone to produce devastating colliery explosions it obstinately refused to go off when wanted to in the internal combustion cylinder where it might do so much good.

Mr. George Roblings.

Mr. George Roblings said Mr. James was to be congratulated upon taking up this subject, and treating it in such a manner as to demand the attention of mining and mechanical engineers, as well as metallurgists. The former should do so for several reasons: (*a*) The generation of steam cheaply. (*b*) The utilisation of inferior fuels which would otherwise be unmarketable or nearly so. (*c*) To convince coal users of the practicability of using a very cheap fuel in place of the more expensive now used, thereby creating a market for the inferior fuel. The benefit to the user of changing over to this system would depend upon whether the saving in labour in the stoke-hold and in the cost of the fuel used would be greater than the cost of running the pulverising and drying plant, together with the interest on and depreciation of the capital expended, also the fact whether a greater evaporative efficiency would be obtained from the same plant, thereby removing the possible necessity of erecting additional boiler plant. Consequently no general rule could be laid down, inasmuch as all these factors vary at every installation.

A simple calculation based on the figures in the paper could be made which would give the minimum amount of coal used per day at which any benefit would be derived, and this again depended largely upon the quality and marketable value of the coal now used, but in any case could not be less than 50 tons per 24 hours (and where at present cheap fuel is used it would be nearer 100 tons), and thus so far as collieries were concerned there would be little incentive to making a change, particularly when consideration was given to the type of boilers used in the majority of places.

Mr. George Roblings.

The portion of the paper with which he was most interested was page 98, and it came as a surprise that anthracite dust with a volatile content of $2\frac{1}{2}$ per cent. could be used. He would, however, like to know where this was obtained, as it was exceedingly low. The absence of figures such as results of tests, etc., detracted somewhat from the value of the statement. Would Mr. James kindly furnish results of tests? It was the more surprising since they knew of the great difficulty in igniting anthracite, a fact which was so well explained in a recent paper by Mr. Roy Illingworth.

He would not say it was impossible, but rather that, as a colliery manager with a large quantity of anthracite duff on hand, the whole field should be explored so that they could if successful inform the large metallurgical people that they had succeeded by the adoption of special methods in using a fuel which would cheapen considerably their cost of production, and at the same time find a ready market for the duff which was the bane of the anthracite trade.

The position, however, was that there was not one anthracite colliery with a boiler consumption sufficiently high to enable a plant being erected and run at a profit even if their boilers were suitable, nor could they be converted until the certainty of success had been assured, inasmuch as they could not risk running their colliery in such a manner as perhaps to have all their men out owing to the failure of the new arrangement. Collieries could not work on intermittent generation of steam. If any experimenting was to be done it should be done at the joint expense of all the anthracite owners, since if success attended the venture, all would derive the benefit.

This would be much more complicated if the idea of Professor Bacon was adopted of cleaning the ash from the fine dust. Even the process of sizing the particles was difficult, and he did not see how any colliery manager could find time

to attend to such a task. Then as to colloidal fuel, the manager of a colliery had quite enough to do to deal with his own coal fuel without taking on oil as well. Mr. George Roblings.

Some amount of American practice had been successfully carried on, but in the absence of any results they could say nothing about them. Taking his own particular case, he was satisfied that it would not be a profitable venture, inasmuch as the difference between the cost of the fuel he used—which for ordinary working consisted of about 50 per cent. of wet and dry grains, from $\frac{1}{8}$ inch to $\frac{3}{16}$ inch, and 50 per cent. duff, while during the strike it was all duff—and the cost of the pulverised fuel would all be on the wrong side. To burn this coal a forced draught pressure of 2 inches to 3 inches W.G. was required, and consequently about 10 to 12 per cent. of dust, containing about 80 per cent. carbon, was blown over into the flues. The temperature of these furnaces was very high, and the fact that this carbon was left unconsumed while suspended made it very difficult for him to imagine how the use of the pulverised anthracite could be attended with success. The coal contained about 4 per cent. to 5 per cent. volatile and under 10 per cent. ash. Want of oxygen could not be urged as the cause, since there was an excess of air entering the furnace, as proved by the low CO_2 percentage in the flue gases. If, however, the supply of air could be regulated so as to maintain a higher CO_2 percentage, then it was possible a temperature might be obtained which would be sufficiently high to enable this dust being consumed. An increase in the percentage from 6 to 13 of CO_2 would mean an increase of over 1000° Fah. in the furnace temperature. This together with the fine grinding of the coal might, however, remove the difficulties. There was certainly a difficulty in igniting this coal and keeping the fires going at cleaning time, owing to the thin fires and the free nature of the coal. The difficulty was

Mr. George Roblings.

well illustrated by the necessity at times where anthracite duff had been tried on chain grate stokers of having to run to other boilers for some burning coal to assist in the ignition, a difficulty sometimes removed by previously mixing with coals of a higher volatile content, obviously with the view of raising the volatile content of the fuel. A similar procedure has been adopted in America to enable coals of low volatile content to be used as powdered fuel. This should appeal to their metallurgical friends in order to enable their using a large percentage of cheap anthracite duff.

With the use of pulverised coal there would be one advantage similar to that possessed by chain grate stokers, when working successfully, in that the necessity to open the doors for stoking or cleaning would be diminished, thereby allowing rushes of cold air, which must reduce the efficiency of the plant and cause unnatural stresses in a machine already highly stressed.

He would like Mr. James to inform them how the ignition was carried out in the lighting up of a furnace, and what were the chances of the jet being kept continuously alight, as the extinguishing of it for a short time would be a very serious matter. Mr. James had given the calorific value of the Lyttle slush in his paper as 12,735 B.T.U. with 23·9 per cent. ash. Was not this too high with the high ash contents ? This slush, he assumed, was from the culm banks, and that the figures given were for the dried coal, since the moisture in these was exceedingly high. Could Mr. James also give them some tests showing the rate of evaporation per pound of pulverised anthracite, as this was the only means they had of comparing efficiencies in a satisfactory manner ?

Finally, they should bear in mind that it was far more difficult to crush anthracite to the requisite degree of fineness than other coal. This was well illustrated at the series of experiments that were carried on at Altofts on anthracite

dust, and it would certainly add to the cost of pulverising, both as to capacities of the pulveriser and wear and tear. This must be added to the costs by Mr. James. Mr. George Roblings.

Mr. ROBERT JAMES said his chief object in preparing the paper was to evoke discussion as to the possible application of powdered fuel to local requirements in South Wales. Powdered fuel possessed many advantages, accompanied by certain disadvantages, such as (1) preparation cost, (2) spontaneous combustion and storage difficulties, and (3) capital expenditure for large plants. To these might be added in wet climates the possibility of the reabsorption of moisture by the coal, which might cause trouble in the pipe lines. Local requirements and considerations must in each case decide the issue after taking into account the cost and type of fuel available. Mr. Robert James.

At the last meeting of the Institute, Mr. W. A. Chamen voiced the opinion of all coal consumers in hoping that the near future will bring some improvement in the quality of the coal available.

Certainly it is quite common for those in charge of boiler plants to find that the coal supplied contains on an average from 20 to 30 per cent. ash. With powdered coal firing, as with grate firing, the less the ash content of the coal the more pleasant it is to meet the engineer, but the conditions of combustion with powdered fuel allow of the better utilisation of coal containing a high percentage of ash.

Each particle of coal is gently injected into the furnace surrounded by the necessary air for combustion, the greater part of the ash being deposited in the large combustion chamber, the lighter particles being carried forward. A certain amount of the ash is deposited on the tubes, and it is necessary with high ash content to use an air or steam blast periodically to blow this fine dust off the tubes. In this way it has been found possible to maintain fires with an ash content of 40 per cent.,

Mr. Robert James.

which under grate firing conditions would, as Mr. Chamen has experienced, put the fires out entirely.

Mr. Morgan in his interesting contribution refers to the loss of metal by oxidation in metallurgical furnaces due to faulty air regulation. The ease with which the fire can be controlled with a system of dust firing enables this loss to be obviated, and in the case of heating and annealing furnaces the saving in loss of metal due to reduced oxidation is quite appreciable.

While of opinion that powdered fuel might be used very successfully in many metallurgical processes, Mr. Morgan does not think it can be successfully applied to open-hearth work. In this opinion the author agrees with Mr. Morgan for the reasons given in the paper, namely, the effect of the dust on the life and efficiency of the chequers. The failures which have occurred in applying dust firing to open-hearth furnaces are chiefly due to this reason. In America attempts are being made to overcome this difficulty by altering the construction of the furnaces, involving removal ash bogies in the downtake flues with a special design of chequer work.

With regard to the effect of the quality of the coal, more particularly its sulphur content, on the finished product, the following figures would appear to suggest that in this respect there is very little difference between powdered fuel and other methods of firing.

The figures were obtained from tests on an open-hearth furnace before and after conversion from oil to coal dust firing, the sulphur content of the coal used being 1·1.

Oil firing—final analysis of steel,			0·025–0·035	%	of sulphur
Coal firing	,,	,,	,,	0·035–0·04	,,	,,

The author is of opinion that the application of powdered fuel firing to open-hearth furnaces need not be considered while there are so many metallurgical operations to which

Mr. Robert James.

it can be readily and successfully applied. Mr. Morgan suggests its application to a furnace of the non-reversing type, provided the necessary temperature can be obtained without the aid of regenerators. The application of dust firing to this type of furnace is described by Mr. C. J. Gadd in connection with a steel tilting furnace, the flow of the gases being always in one direction, the required temperature being attained without the use of regenerators.

In large plants with coke oven and blast furnace gas available powdered fuel should have no application, since the surplus gas should be used in the service of the other furnaces; but it must be admitted that many plants are at present very far from this ideally balanced system of heat distribution. Freshly ground fuel will ignite more readily than fuel which has been pulverised for some considerable period, since the surface exposed would be fresh unoxidised surface. Coal dust from the mines once separated from stone dust would make an ideal fuel, which would only require to be put through a grinder to secure uniformity, which operation would also expose fresh surfaces, and so assist rapid ignition in the furnace.

It is interesting to note Mr. Hill's successful experience with powdered fuel in connection with the firing of rotary kilns in the cement industry, and more recently its adaptation to the firing of steel furnaces.

Mr. Hill criticises the Holbeck system of distribution as being unnecessarily complicated, and referred to the simplicity of the arrangements illustrated in connection with locomotive firing. The problem of getting the fuel from the pulveriser house to the locomotive tenders corresponding to the furnace hopper is particularly simple, since the locomotive can be run to the powdering house and refuelled as easily as taking in water.

Where a large group of furnaces have to be fired it is better

Mr. Robert James.

to have the preparation of the fuel carried out in one central building, both from the point of view of grinding costs and uniformity of product. The essential difference in the various systems depends on the method adopted to transport the fuel to the furnace bunker. The Holbeck system eliminates furnace bunkers by transporting the coal to the furnace by mixing it with air at the pulverising station and sending it round an outward and return main—the fuel being tapped off at each furnace as required.

With furnaces situated some distance apart the system of pipe work tends to become complicated, and from many points of view in certain circumstances it is better to fire the furnaces from a storage hopper near the furnace.

With regard to Professor Bacon's remarks, he agreed that a different title might have better indicated the contents of the paper. In preparing the paper he had in his mind a desire to interest as many branches as possible of the engineering profession as were represented in the Institute. The difficulty of applying powdered coal firing at the present time is the provision of the necessary capital for the erection of the pulverising plant. Such expenditure can only be justified where substantial economies in fuel consumption can be definitely assured, such as 30 per cent. reduction in the coal consumption of puddling furnaces. As to pulverising costs, the 7*s*. 6*d*. per ton given in the paper as an estimate of pulverising 50 tons of coal per day might be brought down to about 5*s*. 3*d*. per ton in an installation capable of pulverising 300 tons per day. The main question for present consideration was whether it was worth while to experiment not with large installations, but by using a type of pulveriser such as the self-contained turbo pulveriser, although they would not perhaps get the desirable degree of fineness of grinding by the latter method. In this way they could get a good idea as to

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whether it would pay to use powdered coal in the operation in which they were themselves interested.

For boiler firing purposes powdered coal should be considered when large stocks of rather poor quality coal were available which would otherwise not find a ready market. While the cost of preparation of powdered coal is readily recognised, it is often forgotten that the coal handling arrangements in a modern stoker-fired boiler house also involve considerable capital expenditure and upkeep charges. In a station of less than 5000 k.w. capacity, the first cost would be rather in favour of the stoker installation, but for very large plants it would favour the powdered coal equipment. Items to be considered in estimating the cost of preparing fuel for a stoker installation would include : Power for stoker and fans (4 per cent. power developed), power for coal handling, labour, repairs for stokers and elevators, plus interest and depreciation on cost of plant.

The more recent developments in power station work had been on the turbine and condenser side; the boiler house remained practically what it was twenty years ago.

Powdered fuel carries with it many advantages which cannot be assessed at a monetary value, such as the elimination of labour difficulties. Whereas in very many instances they had no chain grate stokers or other mechanical means of firing, the labour factor must come in, and he was convinced that, while it would not pay to convert reasonably efficient existing plants to powdered coal firing, they had in the applications of powdered coal firing which he had described a means by which they could secure a system that in the end must prove economical because of its all-round efficiency and its utilisation of low-grade coal.

When the fuel is cut off in all types of boilers fitted for dust-firing, the large volume of heated brickwork in the com-

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bustion chamber retains the heat, so that the steam pressure only falls by a few pounds in several hours. If steam is not required for a considerable period the feeding mechanism can be set in motion intermittently at a rate sufficient to maintain the temperature of the boiler. In this way the life of even the Lancashire type of boiler is not affected to any greater extent than with the present wasteful method of banking fires.

The difficulty of applying Professor Bacon's suggestion of reducing the element of danger from coal-dust explosions to a minimum by suspending the dust in a closed bin of inert gas or of blast-furnace gas would be the trouble experienced in keeping the coal dust in suspension, and high velocities would be required in the transmission pipe lines. This would appear to offer more possibilities of danger than the system of transmitting the coal dust in bulk by compressed air, and mixing it at the burner with the necessary air for combustion. The similar difficulty of keeping the coal dust in suspension in the oil for any length of time is the disadvantage of colloidal fuel for marine purposes. For locomotive firing colloidal fuel is being used successfully, but for this purpose powdered coal possesses distinct advantages. In America the coal saving found with locomotives fired with powdered coal is 25 to 30 per cent. British experiments up to date appear to show a saving of 17 per cent., with the advantages of more sustained boiler power and less cleaning troubles.

Since Dr. Diesel's attempt to burn dust fuel in the cylinders of an internal combustion engine there has been no determined attempt to overcome the difficulty of the cutting action of the ash on the valves, but certain experiments now being carried out with a new type of valve design give promise that the trouble will eventually be overcome.

In reply to Mr. Roblings the method of starting up a furnace fired with powdered coal is as follows. A piece of cotton

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waste is soaked in oil or paraffin and ignited in front of one of the burners. The coal feed is then started, and combustion of the fine particles of coal immediately takes place. The fire soon builds up, and when the brickwork has got thoroughly hot the other burners can be turned on and the fuel ignited by radiation from the hot brickwork.

The ignition of anthracite dust without the admixture of coal of higher volatile content has always been a difficulty, but in America they had adopted finer grinding with a special design of furnace, and they claimed to have surmounted the difficulty of burning anthracite coal in sufficient volume. For the smaller sizes of furnace it might be found necessary to mix with the anthracite a certain percentage of bituminous coal. This had also been found necessary for locomotive work owing to the limited area of the combustion chamber and the absence of any large volume of refractory brickwork. When burning straight anthracite dust in a locomotive the fire has been found to snuff out when the engine slipped, and not to catch easily from the hot brickwork.

The waste culm or slush of the anthracite district of Pennsylvania has the following characteristics :

2 per cent.	through	$\frac{5}{16}$	inch mesh	and	over	$\frac{3}{16}$.
8	,,	,,	$\frac{3}{16}$	,,	,,	$\frac{1}{16}$.
90	,,	,,	$\frac{1}{16}$	,,		

Average analysis of dry coal:

Volatile	6 per cent.
Ash	24 ,,

B.Th.U. per lb., 11,500.

Messrs. Scheffler and Burnhurst, in a paper before the American Society of Mechanical Engineers in June 1919, give brief particulars of tests carried out on several boilers fired

Mr. Robert James. with dust prepared from the above type of fuel, and the figure given in the paper with regard to the calorific value of the anthracite dust of 23 per cent. ash is taken from this paper. The evaporation per lb. of coal, the steam and feed temperatures, are not stated, but the efficiency of the boilers is given as 75 per cent.

At Lykens, Pa., a group of six Babcock & Wilcox boilers, each with an evaporative capacity of about 11,000 lbs. of water per hour, are being fired with anthracite slush. These figures were certainly hopeful, and fully warranted the users of coal in this country tackling the problem with the same earnestness and with the same objects in view as had prompted the Americans. There were large quantities of small coal available, much of which could be powdered and burnt efficiently; the remainder might, after treatment in a Draper type of washer, be made of marketable value with a powdered fuel system in operation.

The discussion was closed with a vote of thanks to the author of the paper, the PRESIDENT remarking that anything which had for its object the saving of coal and the finding of markets for what were at present unmarketable coal products merited and demanded their earnest attention.

The President.

Mr. R. C. Smart. Mr. R. C. SMART read a paper on 'Coal-dust Sampling and Methods Adopted in Practice.'

COAL-DUST SAMPLING AND METHODS ADOPTED IN PRACTICE.

By R. C. Smart, M.C., Assoc.M.Inst.M.E.

COAL-DUST SAMPLING AND METHODS ADOPTED IN PRACTICE.

By R. C. Smart.

In taking coal-dust samples as required by the General Regulations, July 30, 1920, it is necessary to adopt a method or routine of sampling to give reasonable practical accuracy with the class of labour employed in taking the samples.

Given the sample in the correct condition for analysis, *i.e.* sieved through a 28-mesh sieve, the actual laboratory work is not any more exacting as regards accuracy and conscientiousness required than is the case in sampling in the mine.

Before proceeding further, it is not out of place to quote *in extenso* part of the provisions of the General Regulations of July 30, 1920, with reference to sampling :

'Part I.

'4. For the purposes of testing the composition of the dust mixture in any part of a road the following procedure shall be adopted :

'(*a*) Representative samples of the dust shall be collected from the floor, roof, and sides over an area of road not less than 50 yards in length.

'(*b*) The samples collected shall be well mixed, and a portion of the mixture shall be sieved through a piece of metallic gauze having a mesh of 28 to the linear inch.'

The two obscurities that seem to need elucidation or explanation in the foregoing Section 4 are, firstly, what constitutes *part of a road*, and, secondly, what is the meaning of *a representative sample.*

The soundness of the latitude given in the words in italics is not queried; on the contrary, the principle of allowing such latitude is borne out in the smoothness with which the Coal Mines Act, 1911, passed into law and became operative in an industry of the manifold complexities of coal-mining.

To secure the maximum benefit from sampling, one has therefore to decide what the words ' in any part of a road ' are designed to convey.

Considering haulage roads in a mine, therefore, it is evident that the composition of the coal-dust varies from the pit bottom to the working face, and to secure representative samples from such roads indicates that sampling shall be made at such points or sampling stations as may be requisite.

As to what is ' requisite ' to secure representative samples indicates that the sampling stations shall be at such distances apart as the observed character of the dust depositions denote, *i.e.* where any considerable variation in the composition of the deposits occurs or is likely to occur.

Thus the whole matter is naturally dependent on local conditions for the particular mine, seam, and haulage road; in addition, variants in the character of ventilating air currents, friability, and character of the coal in individual seams, the concentration of main haulage roads at junctions or points, and the varying sectional areas of roadways.

The haulage of different types of coal along one haulage road, the method of haulage (head and tail, endless rope, self-acting inclines, or horse), the tonnage output dealt with on individual roads, the character of the floor as to producing non-inflammable dusts from the traffic of men and horses,

and the 'age' of the haulage roads themselves are operative. Also, where a heavy roof weight, etc., is encountered and roads continually require enlarging or 'ripping and widening,' the character and quantity of the dust depositions are affected.

The chief points observed in procuring dangerous or abnormal deposits are the friability of the coal, the concentration of haulage at junctions, and the effect of air currents. That is, broadly speaking, taking haulage roads which have been operative for some years, and which have dealt with reasonable daily tonnages of coal.

It is apparent, then, that parts of a road which are characterised by abnormal dust deposits require sampling in addition to sampling stations fixed at stated distances from other stations.

Sampling, of course, proceeds from the pit bottom or near the pit bottom on each main road working inbye to the subsidiary horse-haulage road close to the working face.

Due to the character of these subsidiary roads in the immediate neighbourhood of the longwall face, the samples taken show a substantial margin on the right side, *i.e.* well over 50 per cent. ash.

Inspection of samples also showed a considerable proportion of fireclay and rock dust, as is expected in roads so close to the working face (in the longwall method).

Also, the roads, comparatively speaking, only last for several years at the most. In sampling horse-haulage roads, therefore, only one sampling station is fixed, and that on the road which deals with the biggest tonnage of coal, so as to secure maximum dust deposition in sample. Apart from sampling stations at points of abnormally heavy coal-dust deposits (due to a variety of local conditions already detailed), the usual interval necessary between stations was found to be 600–800 yards.

Thus progressive changes in the character of the dust

deposits from the pit bottom to the working face are traced. The stations are permanently located and numbered both for the purpose of the preliminary coal-dust sampling and afterwards for the required monthly or periodic sampling. The same observations as to routine apply to the return airways with necessary modifications.

Sampling Routine.—The next point is, having selected the sampling stations indicative of the character of the dust in the haulage roads, to decide what from a practical standpoint constitutes a representative sample.

On p. 30, Fifth Report of the Explosions in Mines Committee, 1913, it states :

> ' For the purpose of examination it is suggested that each sample shall be collected not from one spot only, but from the dust deposited generally on the floor, roof, and sides over some yards of roadway.
>
> ' The several samples collected should be well mixed, and a portion sieved through a piece of metallic gauze (such as safety-lamp gauze) with a mesh of 28 to the linear inch ; any dust that will not pass through such a sieve should be omitted from the determination.'

From this it can be inferred that to secure a representative or typical sample of the coal-dust several samples shall be taken in a length of roadway defined in the General Regulations, 1920, Section 4, as not less than 50 yards.

Following observations in sampling, especially where roads had been ' flue dusted ' some time previously, in order to secure accuracy as to the character of the dust deposition, ten such points were selected in a length of about 50 yards. If only four or five points were taken in the 50 yards, one point would or might have an abnormal amount of flue dust, etc., in it, and the resultant sample would not be a truly representative one.

The ten points are lettered A, B, C, etc., up to J, and are marked off in chalk, usually on bars and legs or timbered places where maximum dust deposition is found. Also, the marks are more easily preserved on 'legs,' etc., than on the 'pack sides' of roads.

The ten points constitute a sampling station, and a list of such stations is left for the samplers who work on the night-shift, as the pit is then not 'drawing' or winding coal.

An area of roadway 18 inches in width is swept from the floor, roof, and sides at each point; this is done at the ten points, and a sample obtained from the material so collected.

Methods of Sampling.—In considering the methods employed it is proposed simply to quote various references to mine-dust sampling, as follows:

(1) 1915. In a paper on 'The American Coal Dust Investigations,' vol. xlix., p. 736, *Transactions of the Institute of Mining Engineers*, by G. S. Rice, is described the use of a sampling screen and scoop.

The construction of the screen and scoop can be followed from Fig. 1; the rubber cork R.C. is removed when the scoop is full to allow the sample to pass into the sampling tin.

(2) 1916. Bulletin 102, Bureau of Mines, U.S.A., on 'The Inflammability of Illinois Coal Dust.' J. K. Clement and L. A. Scholl, on p. 12, mention their method of taking samples of mine dust.

The distinction in the collecting of samples in this Bulletin was the comparison of the inflammability of the fine dust distributed on the roof and sides with the dust that collects on the floor of haulage roads.

(3) 1920. *Transactions of the Institute of Mining Engineers,*' vol. lix., p. 256. R. W. Anderson in sampling takes separate samples from the floor, roof, and sides.

(4) 1921. A. L. Lovatt, in a paper, 'Methods of Stone Dusting,' vol. lx., *Transactions of the Institute of Mining Engineers,* gives a method of daily sampling.

In this method of sampling a small amount is taken from each of ten points in the 50 yards length, from floor, roof, and sides.

(5) In the following method of sampling, whilst there is perhaps nothing of much originality in the apparatus employed, yet at the same time the object has been to devise or use

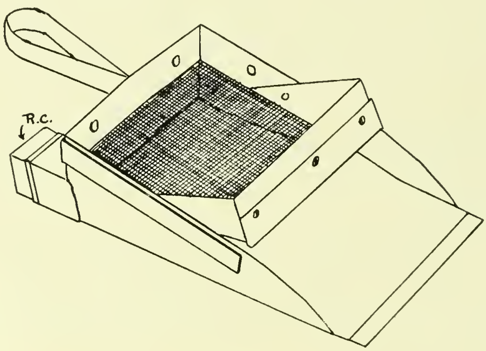

FIG. 1.—DUST-SAMPLING SCREEN AND SCOOP.
(Not to scale.)

apparatus that shall give the maximum accuracy in sampling with unskilled labour.

Firstly, by taking a complete section of floor, roof, and sides 18 inches wide, greater accuracy is assured than in method (4), because the whole of the available dust is taken, and it is not left to the sampler as to where he shall, or shall not, take a small quantity of dust from.

Secondly, it is easy to observe whether the sampling has been done thoroughly by the comparative freedom from dust of the area sampled.

This is a direct and a most important check on the work of the sampler.

Thirdly, Part I., Section 2 (*a*) of the General Regulations, July 30, 1920, says:

'They shall be treated with incombustible dust in such a manner and at such intervals as will ensure that the dust on the floor, roof, and sides *throughout* shall always consist of a mixture containing not more than 50 per cent. of combustible matter.'

The word 'throughout' in italics emphasises in the author's mind the fact that, to obtain a sample from the floor, roof, and sides typical or representative of the dust on these parts of the roads, the only accurate way is to sweep the whole of the dust from these portions over given points in a section of roadway at least 50 yards long. Taking three bottles of equal cubical capacity and filling each with the dust from the floor, roof, and sides respectively, and mixing the whole of the dust thus obtained from the bottles does not ensure that the work this important qualifying word 'throughout' emphasises has been carried out accurately.

If dust depositions were uniform in quantity per unit of superficial area, then it is possible; but as they are not and never can be uniform, it appears that the only way to sample as accurately as possible is to sweep the floor, roof, and sides in narrow sections of 18 inches wide, say, taking as many sections per unit distance as considered necessary.

The time taken to make any observations as to the efficiency of the sampler's work in sampling is small and does not unduly interfere with the routine duties of the person supervising the sampling and dusting of the colliery. In the complete sampling of floor, roof, and sides in 18-inch sections of roadway the following apparatus is used. Fig. 2 shows the apparatus.

1. Sampling shovels (S.S.) the larger $4\frac{3}{4}$ inches wide $\times$ 6 inches long $\times$ $1\frac{1}{2}$ inches deep.

The smaller is $2\frac{3}{8}$ inches wide $\times$ $3\frac{1}{2}$ inches long $\times$ $\frac{3}{4}$-inch deep.

The shovels are, as shown, divided into three equal com-

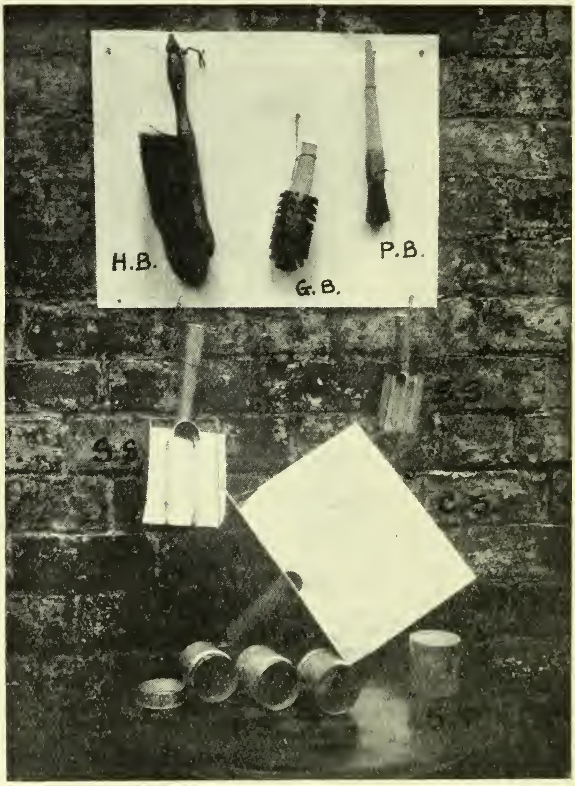

FIG. 2.—SAMPLING OUTFIT.

H.B.—Hand brush.
G.B.—Gauze brush.
P.B.—No. 6 paint brush.
S.S.—Sampling shovels.
C.S.—Collecting scoop.
S.T.—Sampling tin.
M.S.—Multiple box sieve.

partments, the two outer of which have no back to them. Thus in pushing the shovel through a sample of coal-dust two-thirds of the quantity on the shovel can be discarded, whilst the third in the centre of the shovel is placed in a heap from the main pile.

2. 'V'-shaped collecting scoop 12 inches in width, with a tube connection to base, as in Fig. 3, in which a cork is placed. The tube is of sufficient length to form a handgrip for holding scoop whilst sweeping dust on to it from bars, etc.
3. Small hand-brush for sweeping comparatively large smooth surfaces; 2 and 3 can be fitted with

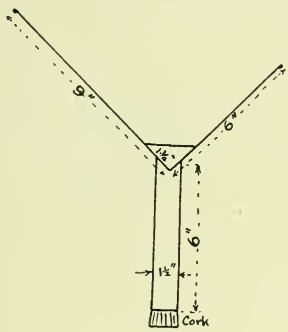

FIG. 3.—CROSS-SECTION OF SCOOP.
(Not to scale).

short wooden shafts for reaching points difficult of access.
4. Small No. 6 paint brush for crevices and small surfaces and sweeping dust from collecting scoop on to sampling sheet.
5. Lamp gauze brush for cleaning the gauzes in the multiple box sieve.
6. Multiple box sieve. In later patterns of this it will be made bigger in diameter, but not so deep, so as to facilitate sieving.
7. Sampling tins for collection of samples, $2\frac{9}{16}$ inches diameter $\times$ $2\frac{3}{4}$ inches deep.
8. Piece of glazed paper 1 yard square and brattice cloth.

Sampling.—The piece of glazed paper forming the sampling

sheet is spread on the top of the brattice cloth in a conveniently situated manhole.

The collecting scoop is then held, say, as in Fig. 5, and the bar swept with hand or paint brush. Due to the long extension

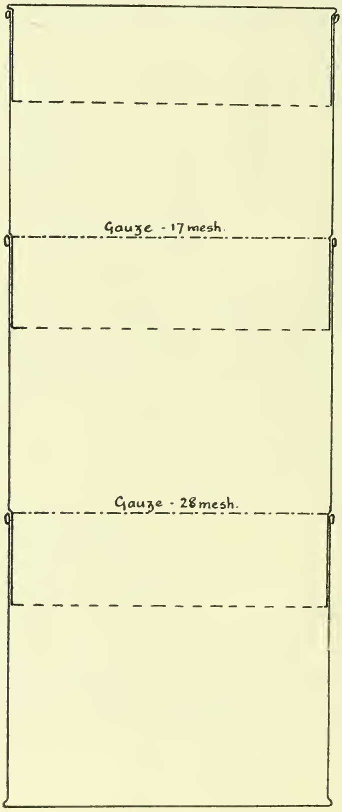

FIG. 4.—MULTIPLE SIEVE.

of the scoop on the one side, very little of the dust is air borne away or lost whilst sweeping the top of bar.

The small side stays on scoop $1\frac{3}{4}$ inches long prevent dust dropping over the edges of the scoop and are not too big to prevent it being held close up to the underside of bars, etc.

The scoop can have edges of sheet rubber to assist in sweep-

ing irregular surfaces and is used to collect dust from roof and sides.

The larger sampling shovel can be used for floor samples, or the collecting scoop, though the shovel is the better of the two to employ.

Dust collected is emptied carefully on to the glazed paper to avoid loss of the very fine dust as much as possible, and after sweeping three or four such points sufficient material is collected to demand treatment.

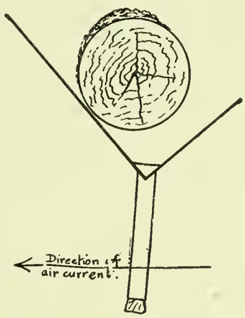

FIG. 5.—COLLECTING SCOOP IN USE.
(Not to scale.)

All coarse pieces $\frac{1}{4}$-inch cube and over are first picked from the pile, which is then thoroughly mixed with the larger sampling shovel.

It is then reduced in bulk, firstly, by means of the large shovel, and secondly, as bulk is reduced, by means of the small shovel. In each case two-thirds of each shovelful of material is discarded, care being taken that each compartment of the shovel is filled with the same amount of dust.

The dust in the outer compartments of shovel is easily discarded by being brushed off at the 'free' end of shovel, the dust in the centre compartment with the 'fast' end being retained.

Finally, when a sample a pound or so in weight is left, it is

sieved in portions through the multiple box sieve, which is fitted with a lid to prevent loss of dust when screening and shaking.

As the collecting box at the base becomes full it is emptied into the sampling tin.

Screening is greatly facilitated by periodic cleaning of the gauzes with lamp-gauze brush, as the holes in them gradually become somewhat choked with coarse material.

After treating ten such points the sample tin is usually three-quarters to practically filled with coal-dust.

Before proceeding to another sampling station the whole of the apparatus is carefully freed from dust, as far as is practicable, by brushing, shaking, etc.

The use of sampling shovel as opposed to 'quartering process' possesses the advantage that it is quicker, besides being a positive and accurate means of securing a small representative sample.

It also lessens the personal equation in taking samples by different samplers, though it cannot, of course, obviate carelessness or negligence in sampling.

The quartering method requires care in building up the cone and controlling the coarser pieces, which normally fall or roll to its base, besides practice in flattening out correctly and quartering, only attained after a certain amount of laboratory experience.

With sampling shovels, after picking coarser pieces from the pile one has only to observe care in shovelling and discarding, providing the mixing of the pile is thorough.

The samples in sampling tins are left in the office with qualifying labels gummed on to them by the sampler. The contents of a sampling tin is then emptied on to a sheet of glazed paper, the heap is thoroughly mixed, and a portion of the dust poured by means of tin into two foolscap envelopes held as in Fig. 6, so that they are each simultaneously one quarter filled.

The envelopes are then straightened out, samples shaken down, and envelopes folded closely, sealed, and then numbered with the sampling station number, which is also written to avoid confusion at the laboratory.

One duplicate is kept, and the other sample is placed in an ordinary correspondence sized envelope, which is closely folded, sealed, and numbered, and is ready for mailing to analyst.

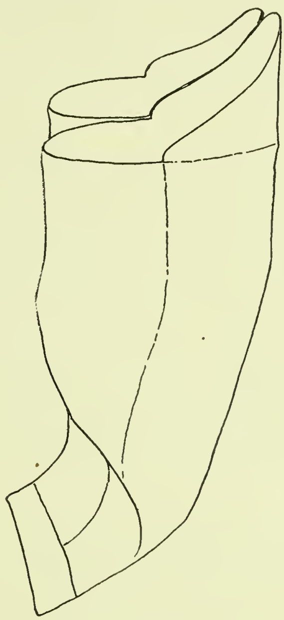

Fig. 6.
(Not to scale.)

If the samples are required for a complete or ultimate analysis and one wishes to avoid absorption of hygroscopic moisture, or they have to be kept for some considerable time, they should be placed in small tins with closely fitting lids and sealed with adhesive tape, or in glass bottles with ground glass vaselined stoppers.

For sampling in cases where samples are forwarded in batches at once to analyst, the envelope method is quite satis-

factory from the point of view of absorption of hygroscopic moisture. Where analysed at the colliery, samples can be dealt with from sampling tins at once.

The envelopes used should, of course, be the official ones in use at the colliery, with the name of the company and its address printed on.

The duplicate coal-dust samples taken prior to stone dusting are kept for future reference. Regarding the monthly samples checking efficacy of stone dusting, only the duplicates for the previous and current months need be kept and the others discarded.

With a view to obtaining, if possible, a still more accurate sample and also a reduction in time factor in taking samples by the more complete removal of all the fine dust from minute crevices, laggings, etc., a vacuum cleaner was experimented with.

(6) *Sample collecting with a vacuum cleaner.*—The type tested was the ordinary manually worked bellows machine. It was tried in a main return airway and on a main intake haulage road.

The chief points noticeable in use may be briefly summarised as follows, since from a practical point of view it appeared to be of little use.

(*a*) The suction end of the nozzle must not be more than $\frac{1}{4}$–$\frac{1}{8}$ inch from the surfaces to be removed, otherwise no material is absorbed.

(*b*) It will absorb fine loose particles up to nearly $\frac{1}{4}$ inch cube in size, if the dust is disturbed and the nozzle buried in it. This effect is much more noticeable in dusty material from the fireclay floor.

(*c*) The coal dust of a fine character on the sides and bars is only affected to any appreciable extent when the surfaces on which it lies are smooth or hard, *i.e.* white-washed timber,

timber smooth and without the bark, rock with a clean fracture and crystalline. Also, it comes readily off a flue dust deposit.

(*d*) The defect in the machine is that after a short time the interstices of the canvas collecting bag become filled with the fine dust, and it is thus blown through with the exhaust from the machine—the bag thus finally containing only a small proportion of the very fine dust, the bulk of it being lost. Some is deposited in the interior of the bellows, etc.

The fine holes in the canvas bag are designed to deal with a material different in shape and quality to the extremely fine, scaly, coal-dust particle.

(*e*) The whole of the apparatus, of course, would require a thorough cleaning before going to another sampling station, which very greatly increases the time taken in sampling as compared with the usual method of hand sampling.

(*f*) The dust absorption is very slow—it took five minutes to clean satisfactorily one square foot of the floor of roadway.

(*g*) The effective W. G. produced by the machine was 2 inches, though up to 3 inches could be obtained by working it vigorously.

Finally, it appears that for any absorption machine to work satisfactorily in dust collection, there must be some means of checking the velocity of the air currents carrying the dust, in order that the dust may be deposited and collected.

Clerical work involves in the first place the keeping of a temporary preliminary sheet (foolscap size) showing the number of the sampling station, date of sampling, and a description of the exact wherabouts of the station. On this sheet the samples as received are checked off. The permanent register is divided up into two parts, the first and smaller forming an index and showing only the individual numbers of the sampling stations, together with their descriptions as to positions, etc.

The second portion forming the bulk of the register is ruled out as below:

Sample No.	Date taken.	Analysis.				% Sat.	Remarks.
		% M.	% Ash.	% V. M.	+ or −		

% V. M. refers to the percentage of combustible matter in the sample.

+ or — shows to what extent the sample is + (over) or — (under) the 50% combustible matter margin required by the General Regulations.

% Sat. is the humidity of the mine air at the time of taking the sample in the pit bottom.

Other than in the index the sampling stations are always referred to by a number.

These numbers in red, contained in red circles, are shown at the points where they are taken on plans kept at the mine.

The lists of samples for posting at the pit top are made out in duplicate and are provisionally in a form showing sample number, date of taking, seam and district in which taken, and the per cent. of combustible matter until a Mines and Quarries Form is issued.

Monthly Sampling.—Having thus as accurately as possible determined the maximum danger zones of coal-dust depositions in the mine, *i.e.* view from (*a*) ash content and (*b*) the bulk and fineness of the deposit, there remains the problem where and when is one to sample on individual haulage roads to secure representative samples as showing the efficacy of stone-dusting measures in vogue.

That is, it appears hardly necessary to adopt the same detailed sampling methods or concentration of sampling stations (every 600–800 yards, etc.) for the monthly sampling after stone dusting has once been commenced. The preliminary stone dusting to secure a working margin above the 50 per cent. of ash line or zone is naturally much heavier than the systematic stone dusting afterwards.

Thus providing vigorous stone dusting as a preliminary, the taking of samples at the maximum danger zones as previously enumerated would appear to be sufficient to ensure a typical sample or test had been made for the particular month in question.

In following months other sampling stations would be taken in rotation besides any new points of abnormal dust deposition that might occur due to fresh development work.

The possibility of securing representative monthly tests with the minimum of sampling is further assured by uniform stone dusting, *i.e.* stone-dusting methods by which a regular quantity of stone dust over a considered length of roadway is deposited or, as far as possible, the same amount in pounds per yard of roadway.

The writer suggests that methods of dusting by compressed air jets, the dust being air borne over considerable distances, appear hardly so satisfactory as dusting machines which distribute stated quantities per yard, etc., by means of fan blasts, etc., or compressed air jets operative over distances up to 200 yards in length. With the adoption of uniform stone-dusting methods as indicated in the previous sentence it seems reasonable to assume that if a sampling station where the ash content had previously been below 50 per cent. is now satisfactorily above that, all other points are adequately safeguarded, and that the one sample or test for that month would be sufficient for the particular haulage road or roadway. Five sampling

points per sampling station are used instead of ten as in the preliminary coal-dust sampling, when the most rigid examination is required.

At one pit dust deposits $\frac{1}{8}$–$\frac{1}{4}$ inch thick were noted about 300 yards from the shaft bottom, up which shaft 600 tons per diem for 280 working days per year were wound. They represented seven years' depositions.

In another pit 150 yards from the shaft slightly heavier deposits were noted spread over a period of five years. About 800 tons per diem for 280 working days per year passed by this sampling station.

In conclusion, the writer wishes to state that the deductions drawn, observations made, etc., are merely as a result of his own experience in dealing with the problem of coal-dust sampling at the particular colliery at which he is engaged, and they are not made in any dogmatic spirit, but rather from the point of view of arousing a spirited discussion.

The whole assurance as to the safety of the mine from the danger of a coal-dust explosion lies in systematic stone dusting, and is dependant entirely on the information given by obtaining samples thoroughly representative in character of the dust deposits on the haulage roads.

The actual analytical work showing the character of the dust samples themselves is mainly a routine process. The only variable is in the rate of the dust depositions on the haulage roads. Accurate sampling therefore becomes the crux of the whole matter.

He also wishes to make acknowledgment to the Institution of Mining Engineers for permission to make quotations from papers as noted in the text.

The Discussion.

The PRESIDENT said they were apt, perhaps, to run away with the idea that coal-dust sampling was a simple matter, but the whole security afforded in the Mines Act Regulations lay in obtaining proper samples. The subject of the paper, therefore, was one of considerable importance, and the author had treated it in a useful manner. The author had told them he took monthly samples, but it seemed to him (the President) that as one colliery road collected far more coal dust than another in the same length of time, any time fixed for taking samples must be short enough to cover the worst road, and the time fixed must vary at different collieries and in different coal-fields. The framers of the Special Regulations evidently realised this point, because no particular time was mentioned so long as representative samples of dust were taken. **The President.**

Professor MOSS (Mining Department, Birmingham University) writes: **Professor Moss.**

I wish first of all to congratulate the author upon this able treatment of an important subject. Sampling is just as important as analysis, and yet it is carried out most indifferently in some districts.

Mr. Smart's method of sampling is sound both from the point of view of practicability and accuracy, but I should be interested to know how many samples could be taken during a shift. The use of the sampling shovels certainly appears a better method than quartering when carried out by the average person. I should be glad if the author would explain why he has thought fit first of all to pass the samples through a 17-mesh sieve. With regard to ascertaining the position of sampling points on a main haulage road, might it not be advantageous to collect separately the dust from roof, floor, and sides, at any particular spot, determining the weight of dust per square

Professor Moss.

foot of area swept, its degree of fineness, and the analysis for each sample? I think such information would tend to clear up some doubtful points in arriving at the efficacy of any particular method of sampling.

Mr. J. Ivon Graham.

Mr. J. Ivon Graham (Assist. Director of Research, Mining Department of Birmingham University) writes:

The author's paper is a welcome one, drawing attention as it does to the fact that the sampling of mine road dust is every bit as important as its subsequent analysis. A sample picked at random in quantity of the order of half an ounce and brought to the laboratory for analysis is a method of sampling which is unfortunately all too common. The results obtained in this way are useless—or worse, in that they are often misleading. It seems most advisable that the sampling should be under the direct supervision of a man of scientific training.

I agree with the author that complete removal of all the dust over any one section is the most satisfactory method of obtaining a sample for compliance with Mines Regulations and to obtain a true test of the composition of the mine dust.

If haphazard samples are taken without paying due regard to the relative amounts of dust lying on floor, roof, and sides respectively, erroneous deductions may be obtained from the analysis of the mixed samples. In this connection the following results of analysis may interest Mr. Smart and members of your Institution. The samples were taken on main roads—with endless rope haulage travelling about $2\frac{1}{2}$ miles per hour—in an up-to-date South Yorkshire pit, where stone dusting has been in practice for the past eight years or more.

The samples have been taken (A.) 250 to 300 yards from pit bottom, *i.e.* inside shaft pillar, and (B.) 500 to 550 yards from pit bottom, *i.e.* about 100 yards beyond the pillar edge. The variation in the ash content of dust from the different positions shows the importance of obtaining a thoroughly 'representative' sample.

Mr. J. Ivon Graham.

The method commonly adopted in South Yorkshire is similar to that described by Mr. Lovatt, samples being taken from the floor, roof, and sides over a 50 yards length of road, and the whole mixed. In some pits, however, in that area the samples from these three sources are not mixed but analysed separately. At the same time observations are made

		Ash Content in sample passing 30-mesh Sieve.		
		Roof.	Sides.	Floor.
		Per cent.	Per cent.	Per cent.
I.	A. 250 to 300 yds. from Pit Bottom .	53·1	77·9	61·9
	B. 500 to 550 yds. from Pit Bottom .	81·9	86·5	73·3
II.	A.	62·3	67·1	54·3
	B.	70·5	81·6	55·8
III.	A.	64·5	70·3	59·0
	B.	63·0	85·0	73·4
IV.	A.	77·2	76·6	69·1
	B.	73·1	85·7	74·8
V.	A.	63·6	76·5	62·4
	B.	80·5	80·2	72·8
VI.	A.	71·2	79·2	66·2
	B.	75·4	86·0	70·7

of the approximate quantity of dust in the different places. This is usually done in a rather rough manner, describing thickness of dust, with approximate thickness of coal dust layer on top, if this be evident, together with statements as to date of last stone dusting, etc. There seems no doubt, however, that the most thorough and accurate method is to remove completely, as Mr. Smart advocates, the whole of the dust over a definite section of the roadway. As he points out, this method has the valuable advantage of seeing at a glance whether the sampling has been carried out efficiently. It has, however, the drawback that considerably more time will be necessary than in the case of what one may describe

Mr. J. Ivon Graham.

as the 'haphazard' methods. If, however, accurate results are desired from the analyst an equal accuracy should be obtained in the sampling process, and the mine agent or manager should be prepared to give the assistance necessary for the most accurate process.

Mr. Smart's method of reducing his large bulk sample to one of small proportions appears on the face of it a decided improvement, as regards time taken in the process and also from the point of view of accurate sampling, over the usual method of 'quartering.'

With respect to the application of the bellows type of vacuum cleaner as a means of clearing any portion of roadway completely, this was tried about eight years ago at a South Yorkshire pit, but was found to be of little real value owing to the various defects outlined by Mr. Smart.

With reference to the sampling and analytical register described by Mr. Smart, in view of the presence of carbonates very often to the extent of 6 per cent. CO_2, it would seem desirable to have a column showing the carbonate content, so that the true combustible matter may be clearly shown. With a shale which is used as a stone dusting material, and containing this amount of CO_2, a mine dust which gave about 47 per cent. combustible matter from the analyses for ash and moisture only would really have another 3 per cent. of non-combustible matter to its credit.

The President.

The PRESIDENT intimated that the paper would be further considered at the next meeting to be held at Cardiff.

Discussion on Mr. R. C. Morgan's paper, 'Causes of Subsidences and the Best Safeguards for their Prevention,' was further adjourned, and the proceedings terminated.

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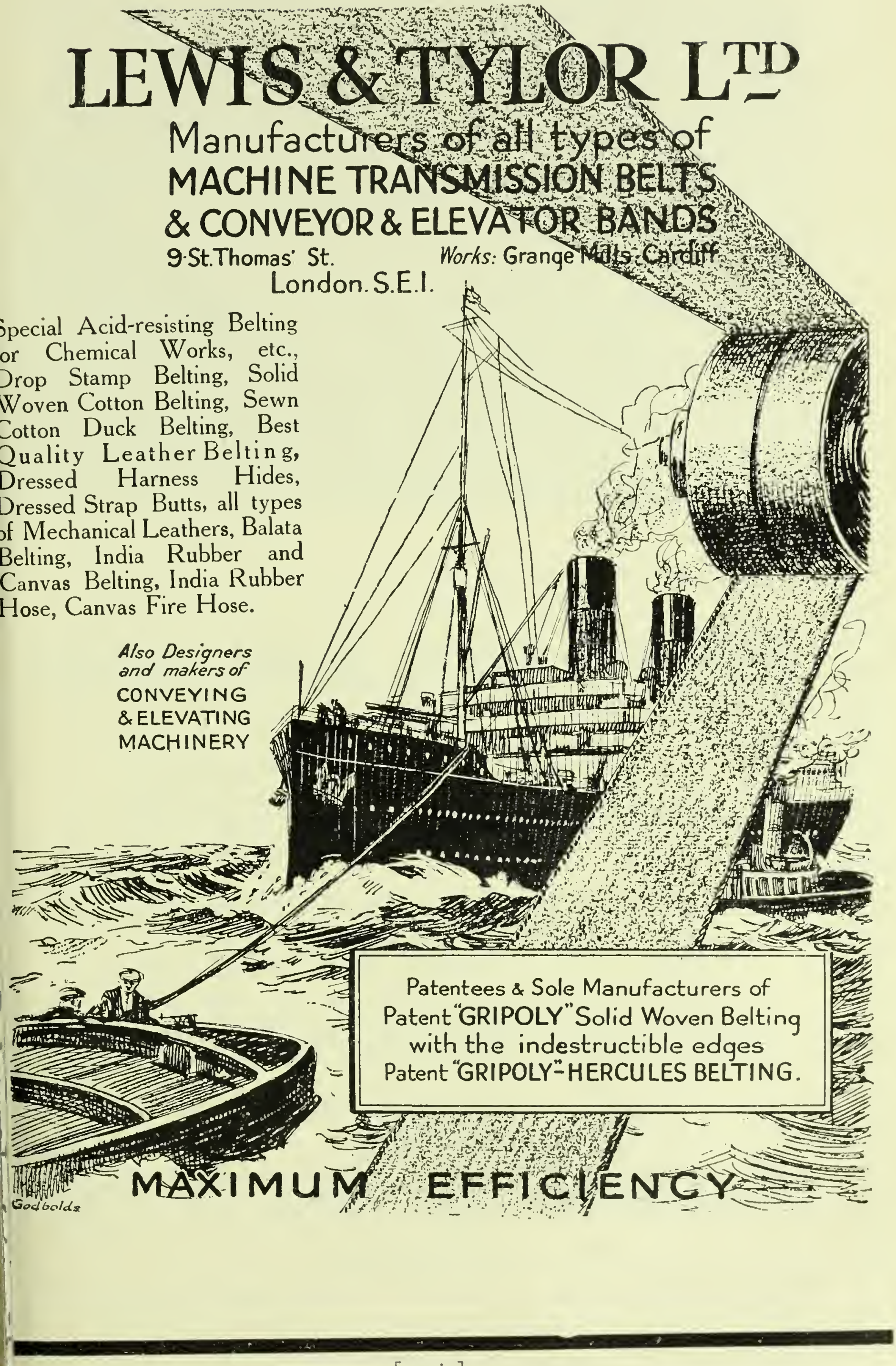
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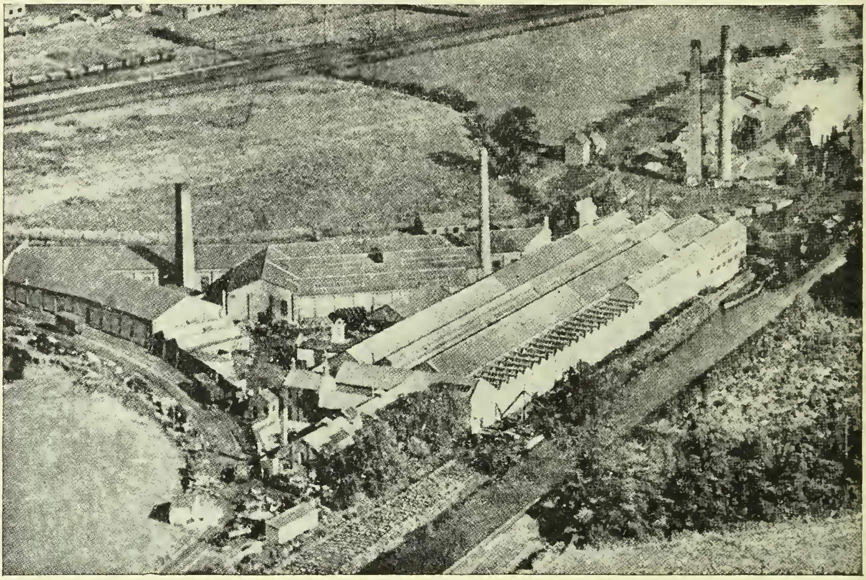

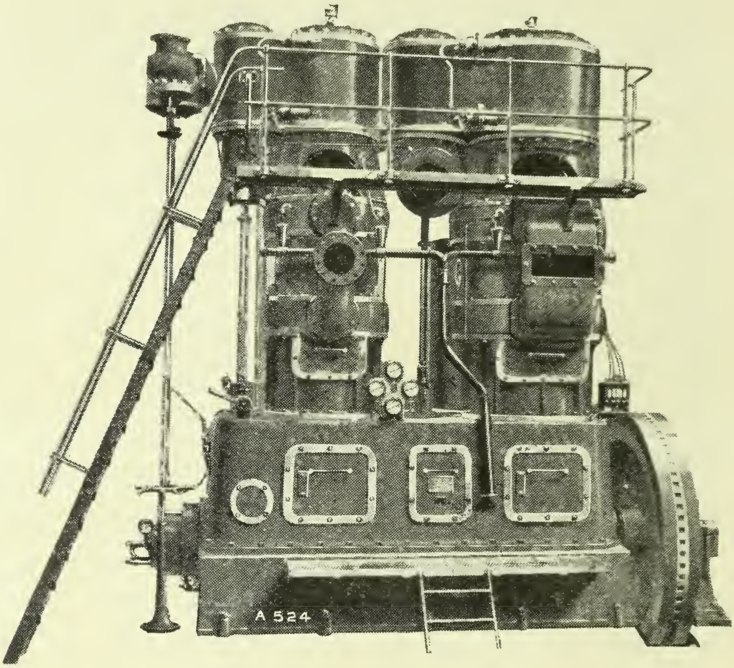

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VOL. XXXVII.] [No. 4

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[EMBRACING THE COAL-FIELDS OF SOUTH WALES AND MONMOUTHSHIRE, THE FOREST OF DEAN, GLOUCESTERSHIRE, AND SOMERSETSHIRE.]

FOUNDED 1857—INCORPORATED BY ROYAL CHARTER 1881.

ORDINARY GENERAL MEETING, CARDIFF, JULY 14TH, 1921.

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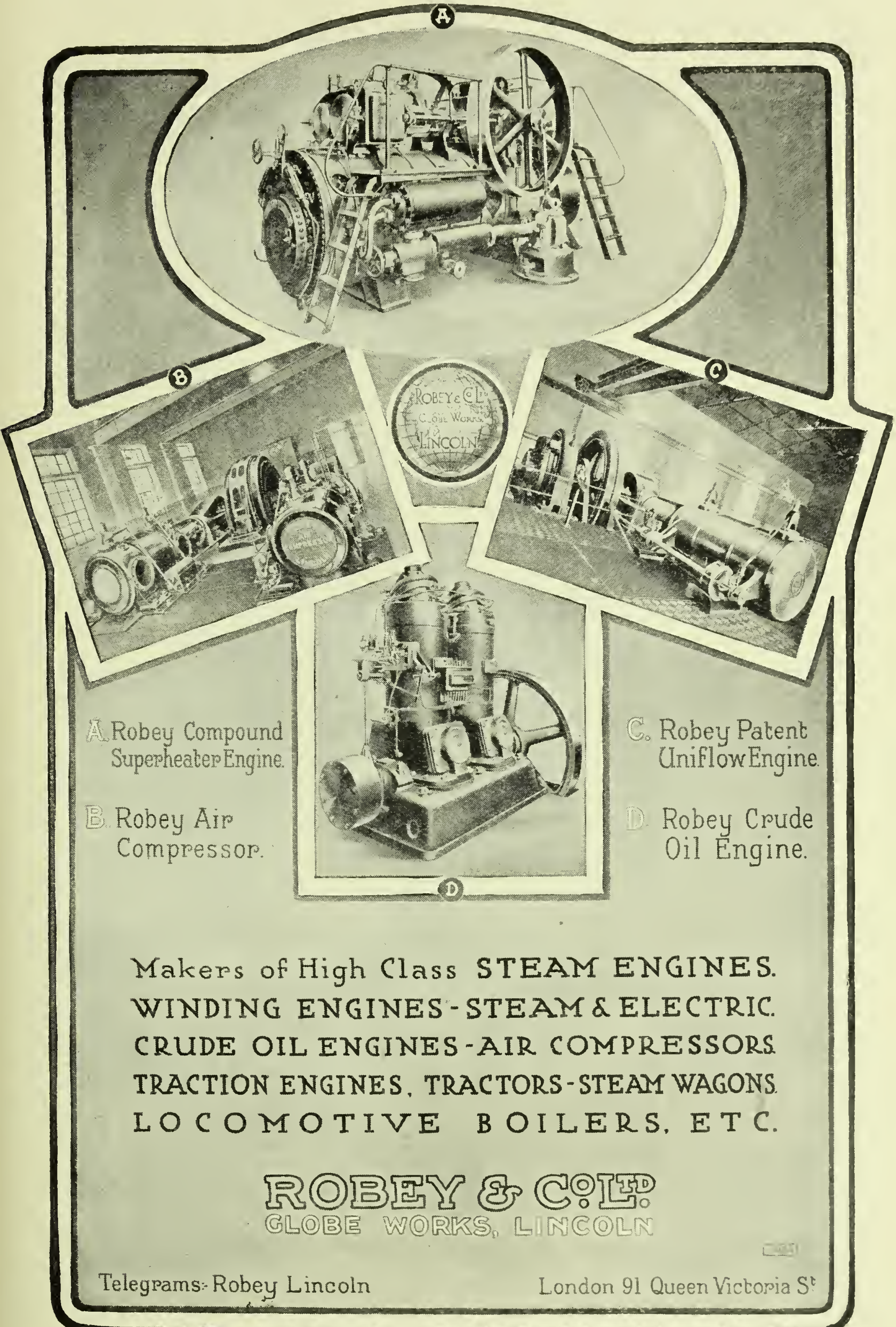
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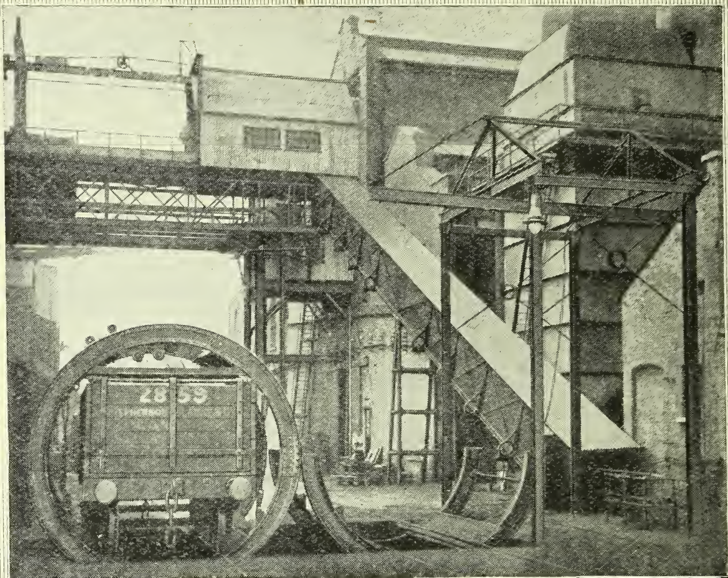

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OF THE

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1921.

	Sessions	
Menelaus, William, M.Inst.C.E. ...	1857–58 ; 1864–65 ...	(Deceased)
Rogers, Ebenezer	1858–59	(Deceased)
Clark, William Southern	1859–60	(Deceased)
Brough, Lionel	1860–61	(Deceased)
Adams, William, A.M.Inst.C.E. ...	1861–62	(Deceased)
Evans, Thomas	1862–63	(Deceased)
Basset, Alexander, M.Inst.C.E. ...	1863–64	(Deceased)
Martin, George	1865–66 ; 1866–67 ...	(Deceased)
Bedlington, Richard	1867–68 ; 1868–69 ...	(Deceased)
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Steel, T. Dyne, M.Inst.C.E. ...	1871–72 ; 1872–73 ...	(Deceased)
Brown, Thomas Forster, M.Inst.C.E.	1873–74 ; 1874–75 & 1891–92 ; 1892–93	(Deceased)
Brogden, James, F.G.S.	1875–76 ; 1876–77 ...	(Deceased)
Laybourne, Richard	1877–78 ; 1878–79 ...	(Deceased)
McMurtrie, James, F.G.S. ...	1879–80 ; 1880–81 ...	(Deceased)
Williams, Edward, M.Inst.C.E. ...	1881–82 ; 1882–83 ...	(Deceased)
Colquhoun, James	1883–84 ; 1884–85 ...	(Deceased)
Hood, Archibald	1885–86 ; 1886–87 ...	(Deceased)
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Stevens, Arthur J., M.I.Mech.E.	1893–94 ; 1894–95	
Martin, Henry William, M.Inst.C.E.	1895–96 ; 1896–97	
Jordan, Henry Keyes, D.Sc., F.G.S.	1897–98 ; 1898–99	
Evens, Thomas, M.Inst.C.E. ...	1899–00 ; 1900–01	
Riches, T. Hurry, M.Inst.C.E. ...	1901–02 ; 1902–03 ...	(Deceased)
Hann, Edmund Mills, M.Inst.C.E.	1903–04 ; 1904–05	
Deakin, Thos. Hedges, M.Inst.C.E.	1905–06 ; 1906–07	
Wight, William Dundas	1907–08 ; 1908–09 & July 1911 to Dec. 1911	
Rees, Ithel Treharne, M.Inst.C.E.	1909–10 ; 1910 to July 1911 ...	(Deceased)
Galloway, W., D.Sc., F.G.S., F.I.D.	1912	
Elliott, A. C., D.Sc., M.Inst.C.E.	1913	(Deceased)
Atkinson, Sir W. N., LL.D. ...	1913 (May 22 to Dec. 31, 1913)	
Wales, Henry T.	1914	
Griffiths, E. H., M.A., F.R.S. ...	1915	
Stewart, Wm.	1916	
Bramwell, Hugh, O.B.E.	1917	
Tallis, John Fox	1918	
Dawson, Edward, M.I.Mech.E. ...	1919	
Lewis, J. Dyer	1920	

THE SOUTH WALES INSTITUTE OF ENGINEERS.

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Brown, W. Forster, M.Inst.C.E.	Session 1921.

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Martin, Henry W., M.Inst.C.E.	1895–96, 1896–97.
Jordan, Henry K., D.Sc., F.G.S....	1897–98, 1898–99.
Evens, Thomas, M.Inst.C.E.	1899–00, 1900–01.
Hann, E. M., M.Inst.C.E.	1903–04, 1904–05.
Deakin, T. H., M.Inst.C.E.	1905–06, 1906–07.
Wight, Wm. D.	1907–08, 1908–09 & July to Dec. 1911.
Galloway, W., D.Sc., F.G.S., F.I.D.	1912.
Wales, Henry T.	1914.
Stewart, Wm.	1916.
Bramwell, Hugh, O.B.E.	1917.
Tallis, John Fox	1918.
Dawson, Edward, M.I.Mech.E.	1919.
Lewis, J. Dyer	1920.

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Johnson, Wm.	Bridgend.
Vachell, Theodore, A.M.Inst.C.E.	Newport.
Chamen, W. A., M.I.E.E.	Cardiff.
Hood, W. W.	Cardiff.
Thomas, Hubert Spence...	Whitchurch, Glam.

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Jones, Howell R.	Dowlais.
Gilbertson, Francis W.	Pontardawe.
O'Connor, W., F.G.S.	Argoed, near Newport.
Davison, J. W.	Pontypridd.
Llewelyn, Sir Leonard W., K.B.E.	Newport, Mon.
Thomas, Trevor F., A.M.Inst.C.E.	Whitchurch, Glam.
Nicholas, Benjamin	Pontypool.
Jacob, F. Llewellin	Ferndale.
Hutchinson, J. W.	Tondu.
Seyler, C. A., B.Sc.	Swansea.
Hann, E. L.	Aberdare.
Davies, D. Farr, F.G.S.	CrossHands, Llanelly.

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Established in 1904, and to be awarded—in the discretion of the Council—for the best Papers read in each Presidential term.

1904.

THE FIRST GOLD MEDAL

WAS AWARDED TO

Mr. HENRY K. JORDAN, F.G.S.

PAPER, "THE SOUTH TROUGH OF THE COAL FIELD, EAST GLAMORGAN.

1908.

THE GOLD MEDAL

WAS AWARDED TO

Mr. EDMUND MILLS HANN, M.Inst.C.E.

PAPER, "A RECENT PLANT FOR THE UTILISATION OF SMALL COAL."

1910.

THE GOLD MEDAL

WAS AWARDED TO

Mr. HUGH BRAMWELL

PAPER "RE-SINKING AND RE-EQUIPPING THE GREAT WESTERN COLLIERY COMPANY'S MARITIME PIT."

1912.

THE GOLD MEDAL

WAS AWARDED TO

Mr. GEORGE G. HANN.

PAPER, "SINKING AND EQUIPPING THE PENALLTA COLLIERY."

THE INSTITUTE GOLD MEDAL.

In 1917 by Resolution of Council the name of the Medal, "The President's Gold Medal," was changed to that of "The Institute Gold Medal."

1917.

THE GOLD MEDAL

WAS AWARDED TO

Mr. GEORGE DOUGLAS BUDGE.

PAPER, "STONE DUSTING IN STEAM COAL COLLIERIES."

LEWIS PRIZE.

Founded in 1895 by the late LORD MERTHYR of SENGHENYDD (Past-President), K.C.V.O., M.Inst.C.E., for the best Papers on subjects connected with Practical Mining and Practical Engineering, including Metallurgy.

1898. A First Prize was awarded to Mr. E. H. Thomas for his Paper on "Haulage," and a Second Prize to Mr. G. E. J. McMurtrie for his Paper on "Sinking."

1900. A First Prize was awarded to Mr. S. A. Everett, and a Second Prize to Mr. E. H. Thomas, for Papers on "Colliery Surface Arrangements."

1901. A Second Prize was awarded to Mr. Ralph Hawtrey, a Student, for his Paper "The Best and Most Economical System of Working Seams of Coal of Moderate Inclination in South Wales."

1904. A First Prize was awarded to Mr. H. D. B. How, A.M.I.E.E., for his Paper "Coal Winding Machinery."

1905. A First Prize was awarded to Mr. W. Waplington for his Paper "Description and Design of the Best Arrangements of Equipment of the Bottom, with a Radius of 400 yards, of a Pair of Pits to be Upcast and Downcast Respectively."

1906. A Second Prize was awarded to Mr. George Roblings for his Paper "Separation (Sizing) and Washing of Coal."

1907. A First Prize was awarded to Mr. Daniel Davies, and a Second Prize to Mr. Gath J. Fisher, for their Papers on "Pumping and Drainage," and also on "Sinking Shafts."

1908. A First Prize was awarded to Mr. H. A. Staples, a Second Prize to Mr. George Roblings, and a Third Special Prize to Mr. M. D. Williams, for their Papers "As to the Best Methods of Working Seams of Coal in Steep Measures."

1909. A First Prize was awarded to Mr. William Trimmer, and a Second Prize to Mr. C. W. Jordan, A.M.I.Mech.E., for their Papers on "General Lay-out and Equipment of a Complete Set of Engineering Shops for a Modern Colliery with an Output of about 2,000 tons per day."

1910. A First Prize was awarded to Mr. George Roblings, and a Second Prize to Mr. Noah T. Williams, for their Papers on "Washing and Sorting of Small Coal."

1913. Special Prize awarded Mr. Will Gregson for his Paper "The Most Approved Methods of Hauling the Coal from the Working Faces to the Pit Bottom."

1914. Special Prizes awarded Messrs. J. Williams and S. R. Cound for their Papers on "How to Improve Welsh Tinplate Rolling-mill Practice."

1918. A First Prize was awarded to Mr. W. T. Lane, and a Second to Mr. W. H. Casmey, for their Papers on "Fuel Economy in Power Production (or Utilisation of Waste Heat)."

1920. A First Prize was awarded to Mr. R. C. Morgan for his Paper on "Causes of Subsidences and the best Safeguards for their Prevention."

1921. Subject selected: "Improved Mechanical Methods for bringing Coal from long distances in view of the necessity for Increased Output." 1st Prize £20, 2nd £10.

INSTITUTE SCHOLARSHIP IN ENGINEERING.

Granted by the Council in 1904, and tenable for three years at the University College of South Wales and Monmouthshire.

1904.—An EXHIBITION of £60, awarded to Mr. ERNEST CLARKE STROUD, Chatham.

1905-08.—A SCHOLARSHIP of £70 per annum, awarded to Mr. E.C. STROUD.

1908-11.—A SCHOLARSHIP of £70 per annum, awarded to Mr. IVOR RICHARD COX, Cardiff.

1912.—An EXHIBITION of £60, awarded to Mr. VICTOR JOHN FRENCH, Chatham.

1912-15.—A SCHOLARSHIP of £70 per annum, awarded to Mr. VICTOR JOHN FRENCH.

1915-18.—A SCHOLARSHIP of £70 per annum, awarded to Mr. E. W. H. KNIGHT, Devonport,

NOTE.—Mr. Knight was unable to take up the Scholarship he had won, and an honorarium of £10 was granted him by the Council, also a Certificate to the effect that he had won the Scholarship.

1919-12.—An EXHIBITION of £13 (plus a bonus of £15) per annum, awarded to Mr. E. G. DAVIES, Cardiff. (Won in 1915.)

1919-21.—A SCHOLARSHIP of £70 per annum, plus a bonus of £15 per annum, awarded to Mr. MYRDDIN DAVID, County School, Porth, and

1919-20.—An EXHIBITION of £30 per annum for two years, awarded to Mr. J. SELWYN CASWELL, EbbwVale.

NOTICES.

The EDITOR of these Proceedings is directed to make it known that the Authors alone are responsible for the facts and opinions contained in their respective Papers, and the individual speakers for their statements made in discussion.

PROCEEDINGS.

Back Numbers of the Proceedings have now been bound, from Vol. I. inclusive, in Volumes, in strong Duro-Flexile Cloth, and may be obtained from the Secretary at £1. 1s. per volume, or separate back numbers can be had at the various prices marked on the covers.

CHANGE OF RESIDENCE.

The SECRETARY would be obliged by Members notifying to him any alteration in their addresses at the earliest date.

INSTITUTE BUILDING.

The INSTITUTE, Park Place, Cardiff, is open for the use of Members on Week-days from 10 A.M. to 5 P.M.

The NEW LIBRARY is now open for the use of Members, and the technical journals and other periodicals will be found on the tables in that room, instead of in the Council Chamber.

SPENCE THOMAS SCHOLARSHIP.

(Founded in 1918 by Mr. H. Spence Thomas for the encouragement of the Members of the Associations of Students of the Institute.)

The interest on £1,000 5 per cent. War Loan Stock shall be devoted to the Scholarship.

The Holder of the Scholarship must be a Member of one of the Students' Associations of the Institute, and must be a Student at one of the Colleges, Schools, or Institutions recognised as suitable by the Council of the Institute.

The Council of the Institute shall award the Scholarship upon Reports presented for its consideration by the Heads of any of the above Colleges, Schools, or Institutions, on the completion of one year's study by any student.

The College, School, or Institution shall present an annual report to the Council on the work and progress of the Scholar to whom the Scholarship shall have been awarded, and the Council retains the right of withholding or cancelling the Scholarship, if in its opinion the progress of the Scholar is unsatisfactory.

In the award of the Scholarship the professional knowledge and practical experience of the candidate shall be taken into consideration.

No candidate will be elected to the Scholarship until he has satisfied the Council that his physical condition is satisfactory.

The Scholarship shall be awarded for a term of one, two, or more years in the discretion of the Council. The Scholar to briefly report at the end of each year upon the work accomplished.

The Council reserves the right to withhold the Scholarship if no candidate of sufficient merit presents himself.

1919–1921. The Spence Thomas Scholarship of £50 per annum was awarded to Mr. William John Gilbert, Nantyglo, for a period of three years, tenable at the School of Mines, Treforest.

UNIVERSITY COLLEGE of SWANSEA

South Wales Institute of Engineers' Scholarship in Engineering.

A Scholarship of the value of £70 per annum, tenable in the University College of Swansea for three years, will be offered for competition by the Council of the South Wales Institute of Engineers at the Entrance Scholarship Examination, which will be held at the College, Mount Pleasant, Swansea, on September 12, 1921.

The following are the special regulations and conditions attached to the award of the Scholarship:

1.—The Examination will be conducted by the College at the same time as the Entrance Scholarship Examination, and the Council of the College will submit the conclusions of the Senate to the Council of the Institute, who, after consideration of the Senate's report, will select the scholar.

2.—The College will present a report at the end of each College Term on the work and progress of the scholar, and the Council of the Institute retains the right of withholding the Scholarship if, in its opinion, the progress of the student is unsatisfactory.

3.—The scholar will be expected to have completed the Matriculation Examination of the University of Wales, or some equivalent Examination, but this qualification may be waived in cases where there is evidence of *exceptional* ability in professional subjects. In the latter case, however, the scholar will be required to pass the Matriculation Examination, or some equivalent Examination, at or before the end of his first year in College, and in such a case the Institute will consider the advisability of granting an Exhibition of lesser value for his first year or of extending the Scholarship for a fourth year.

In the case of a candidate who gives evidence of exceptional ability in his scientific and professional subjects, but who has not passed the Matriculation Examination or its equivalent, and who does not wish to pass such an Examination at the end of his first year, thereby enabling him to prepare for the degree of B.Sc. in Engineering in the University of Wales, the Council is prepared to allow the holder of the Scholarship to dispense with Matriculation, provided he submits a suitable scheme of research, to be carried out under the direction of the Professor of Engineering, and appears to possess the necessary qualities for successfully undertaking such research.

4.—In the award of the Scholarship the practical and professional experience of the candidate will be taken into consideration.

5.—The holder of the Scholarship will, during his tenure thereof, be admitted into the privileges of a Student of the Institute.

6.—In the Examination the following subjects are obligatory:

English Essay (1 paper).	Applied Mathematics (1 paper).
Pure Mathematics (1 paper).	Applied Mechanics (1 paper).

In addition, the candidate must take two and not more than two of the following subjects:

(*a*) Chemistry (1 paper).	(*e*) Geometric and Engineering Drawing (1 paper).
(*b*) Physics (1 paper).	
(*c*) Geology (1 paper).	(*f*) Electrical Technology (1 paper).
(*d*) Heat Engines (1 paper).	

7.—The age of the candidate on April 1 prior to the date of the Examination must not exceed 25 years. In the case of a candidate who intends to pursue a scheme of research, this restriction need not be held to apply.

8.—No candidate will be elected to the Scholarship until he has satisfied the Council of the Institute that he is of sound bodily constitution. The Council also reserves the right to suspend the Scholarship should the physical condition of the holder subsequently become unsatisfactory.

9.—The Council of the Institute reserves the right of withholding the Scholarship if no candidate of sufficient merit presents himself.

10.—Every candidate must be a British subject.

11.—Every candidate must sign a declaration of his intention to enter some branch of the Engineering profession. The holder of the Scholarship will be expected to devote the whole of his time and energy to the pursuance of a course of study or research approved by the College Authorities. He may not become a candidate for any other Scholarship, exhibition, or remunerative position, unless special permission has been sought and obtained from the Council of the College and the Council of the Institute.

Intending candidates may obtain from the undersigned the General Regulations affecting the Entrance Scholarship Examination, and a printed Form of Application for admission to the Examination for the Scholarship in Engineering, which must be returned to the Registrar properly filled in on or before August 1, 1921, together with a certificate of birth and testimonials of good conduct.

EDWIN DREW, Registrar.

University College Offices:
Dumbarton House,
Bryn-y-mor Crescent, Swansea.

ADVERTISEMENTS.

CONTENTS.

No. 4. Volume XXXVII., issued Sept. 24th, 1921, price 10s.

PROCEEDINGS.

An Ordinary General Meeting of the Institute was held at the Institution, Cardiff, on Thursday, July 14, 1921.

The chair was taken by the President, Mr. W. Forster Brown, M.Inst.C.E.

The minutes of the preceding Ordinary General Meeting held at Swansea on May 31, 1921, were read and confirmed.

Election of Members.

The following candidates for admission to the Institute were declared to be duly elected :

As Members.

Evans, Thomas William . . . Porth, Glam.
Jones, Jacob Carlos, J.P. . . Wollongong, New South Wales, Australia
Moss, Watkin . . . . . Porth, Glam.
Williams, John Stephen . . . Porth, Glam.

As Associate Member.

Thorne, Charles Ernest . . Johannesburg, South Africa.

As Associate.

Williams, Reginald Gordon . . Pontypridd.

Cardiff University College Engineering Association of Students of the Institute.

As Associates and Students.

HOWSE, ARTHUR FLEETWOOD . .	Blaenavon, Mon.
JENKS, NORMAN JOHN . . .	Cardiff.
MORT, TREVOR	Mynyddbach, Landore, Glam.
WATKINS, DAVID EDGAR . . .	Abercrave, Breconshire.
WATKINS, JOHN ELWYN . . .	Abercrave, Breconshire.

East Glamorgan Association of Students of the Institute.

As Associate.

MORGAN, WILLIAM CASPER . .	Troedyrhiw, Glam.

Mr. J. Smurthwaite.

The President.

The PRESIDENT before proceeding with the business of the meeting referred to the illness of Mr. J. Smurthwaite, who had for a number of years recorded the proceedings of the Institute. He regretted to say that Mr. Smurthwaite had been very ill and had undergone a very serious operation. He was glad, however, to inform the members that he was much better. He proposed that a vote of sympathy in his illness be sent to Mr. Smurthwaite by the members, expressing a sincere wish for his speedy recovery.

The resolution was unanimously agreed to, and the secretary was requested to see that it was conveyed to Mr. Smurthwaite.

Causes of Subsidences and the Best Safeguards for their Prevention.

By. R. C. Morgan.

(For Paper *vide* Proceedings, Vol. XXXVII., No. 1, p. 49, and for Discussion thereon *vide* Proceedings, Vol. XXXVII., No. 2, p. 144.)

The President said this paper had been before them on several occasions, but they had not had an opportunity of discussing it fully. If there was no one who wished to take part in the discussion, he would invite Mr. Morgan to reply to observations that had already been made. **The President.**

Mr. R. C. Morgan, replying to the discussion, said he would like first of all to thank the members for the kind way in which they had received his paper. He would also like to be allowed to correct one mistake which had been made. He referred to the statement that he was a student at the School of Mines. That was not correct. He had been a student there some years ago, but had been for some time a colliery manager, so that they would see that he was not as young as he looked. **Mr. Morgan.**

Mr. H. W. Halbaum first of all remarked on the scarcity of the author's data, which is, of course, quite true. However, when he (the author) asked for more data from outside sources he had in mind a conversation with Principal Knox some time ago, when the possibility of obtaining data through students at the School of Mines was discussed. This data would be, of course, not for his own use, but for a committee, composed of men interested in the subject, to discuss.

Perhaps some day this will be done, but in any case the gentlemen in charge of the various colliery undertakings who are members of this Institute could materially assist in this work by encouraging those students who work under them when the time comes. Perhaps Mr. Halbaum might

Mr. Morgan. understand that his request was not as innocent as it appeared.

Mr. Halbaum was correct when he criticised him for his opening remarks, but if he will substitute the word 'law' for 'theory' the author thinks Mr. Halbaum will agree with him. The next point which Mr. Halbaum raised refers to the bottom of p. 56, where it is stated that the depth of this beam, being the thickness of the absolute roof, would be greater than one-sixth of the length. Of course everyone knows that the absolute roof is composed of various beds of rock of varying strengths and consistency, and doubtless the position of the neutral zone would be indeterminate. Probably the upper layers of the 'beam' would cease to become effective members and would tend to become loads as Mr. Halbaum has shown in his paper to which he refers. Still, if he studies the table on p. 62 he will find that the length of the beam referred to varies from 40 to 105 feet. One-sixth of this length will be approximately 17 to 18 feet. Doubtless Mr. Halbaum has seen falls of roof underground to a greater height than 18 feet. In the particular seam to which the results mentioned refer, falls of 30 to 40 feet are not unknown. It is evident that these falls of roof cannot extend above the neutral zone, so that the thickness of the beam must of necessity exceed one-sixth of the length.

The author was afraid he did not know enough of the subject to write the supplementary paper suggested by Mr. Halbaum, but it was certainly an interesting question.

Mr. Halbaum remarks that the results of District No. 3 seem somewhat discordant. If he will refer to p. 65 he will see that the writer had dealt fully with this matter. The two cases of varying surface subsidence quoted by Mr. Halbaum are very interesting and serve to show that the nature of the strata in the absolute roof requires to be known when dealing with this subject.

Mr. Morgan.

If Mr. Halbaum is correct in his assertion that the lateral thrust is largely a spent force in South Wales, then he is perfectly correct in stating that the intense crush is accounted for by this fact. The author would like to know what grounds Mr. Halbaum has for making this statement. He knew of several cases where the lateral thrust is very much in evidence (he referred to several of the most recent deep sinkings where great trouble has been experienced in keeping the pit-bottom from closing in), and he had not heard that the squeeze on the workings was any the less in consequence. Personally he favoured Principal Knox's theory of the effect of the unbalanced loads due to the hills. However, although not in agreement on all points, he wished to thank Mr. Halbaum for his helpful criticisms.

He felt sure that after hearing his opening remarks Mr. W. O'Connor would understand why he carried out his small amount of research work in the unsuitable area referred to by him. That the author realised its unsuitability at the time is shown by his remarks on p. 72. As far as the seam being in virgin ground is concerned, actually three out of the four districts are in virgin ground. As to the question of the geological structure of the absolute roof, generally speaking the hills are composed of the Pennant Series, the horizon of the No. 2 Rhondda Seam being a few yards above the floor of the valley.

He had nothing to say regarding Principal Knox's remarks except that he thought they added to what value the paper possessed.

He agreed with the President's remarks regarding the effect of the hardness of rock on the angle of pull, but did not think he was correct when he stated that the angle of pull when intercepted by the fault (referred to in para. 7, p. 69) would become greater. In this case the fault was

Mr. Morgan. overhanging the district (see Fig. 3) and the prime face would tend to draw into the hade of the fault and consequently become more nearly vertical. He was not stating a general case but a particular instance. The exception to prove the rule.

The particulars of the results obtained with hydraulic stowing in Germany were taken from a paper on Mining Subsidence by Principal Knox. The reference quoted in the paper was as follows :

Herr Buntzel, *Zeitschr. f. Berg., Hütt. u. Salinenw.*, vol. lix, 1911, p. 293.

The author wished, in conclusion, to thank the members for their kind interest and attention.

The discussion was closed with a vote of thanks to the author of the paper, the President remarking that the paper was a very interesting one, and the subject had been dealt with in a very scientific way.

The President.

Coal Dust Sampling and Methods Adopted in Practice.

By R. C. Smart, M.C., Assoc.M.Inst.M.E.

(For Paper *vide* Proceedings, Vol. XXXVII., No. 3, p. 239.)

The President. The President stated that discussion on this paper was commenced at the last Swansea meeting, but there were few present on that occasion. He invited discussion, intimating that Mr. Smart had telegraphed to say that he was unable to be present, but he would reply in writing to any comments that might be made.

Mr. G. D. Budge. Mr. G. D. Budge said he was glad that Mr. Smart had drawn attention to the abnormality of certain places of sampling. Mr. Smart pointed out, 'It is apparent, then, that parts of a road which are characterised by abnormal

dust deposits require sampling in addition to sampling stations fixed at stated distances from other stations.' He thought that was a very important point in the paper, because in sampling, say, a haulage road, if they took merely the roof, sides, and floor, and did not go above the timber at all, he did not think that a fair sample could be got of that part of the road. It was absolutely essential in the case of sampling main haulage roads to have regard to the dust which had accumulated in cavities above the timber. He saw that Mr. Smart had drawn attention to this fact. Personally he considered it very important that samples should be got from the cavities. He did not think for one moment that a 50 per cent. non-combustible mixture on the road itself would be effective at all if ignition took place in a cavity above the timber unless the dust in the cavity was of such a composition that it contained at least 20 per cent. of non-combustible matter. In that case he thought there would be a chance of a 50 per cent. mixture being of some good. They should endeavour to find out something about the cavities, and although they could not expect to bring them to anything like a 50 per cent. mixture they could get them to 25 per cent., and that he believed was sufficient for the purpose. **Mr. G. D. Budge.**

Mr. J. DYER LEWIS said that Mr. Smart's paper had come before the Institute at a very opportune time—when most of the colliery managers and mining engineers hardly knew exactly what to do in connection with the new regulations which were now in force. He thought there was a misprint on page 240 in describing the method of haulage as 'head and tail,' main-tail he expected it should be. The sampling of dust was not such an easy matter as people might think. It was very difficult. Mr. Budge had already pointed out the very great importance of having a part of the sample taken **Mr. J. Dyer Lewis.**

Mr. J. Dyer Lewis.

in a haulage road from the higher cavities in the roof. Then again as to the representative sample mentioned on p. 240, first paragraph, which read 'what constitutes part of a road, and, secondly, what is the meaning of a representative sample.' He took it a representative sample really meant that which was taken over that 50 yards in length, not a representative sample over the whole of the haulage road. At the beginning he would say it would be most important to have samples taken over parts of the haulage roads right away from the pit to the face, so as to find out exactly where the worst places were, before fixing different spots where samples should be taken. It often happened where there were narrow sections of roadways, the air current was ever so much stronger and more dust was consequently blown off the trams at that spot. The dust was then deposited, either in-bye or out-bye, in accordance with the way in which the current was travelling, in the open spaces which were wider than in the narrow places referred to. It did not seem to him that Mr. Smart paid sufficient attention to subsidiary roads up to the working face. Samples had to be taken practically up to the working face, so as to know exactly the condition of the dust there. As they all knew, a very large number of explosions had happened quite near the working face, and therefore the face itself must be just as well protected as the main haulage roads. This was especially important now in places where conveyors were working, for these were parts of the mine which were rarely ever dusted. In so far as the protection of our roadways was concerned he had no doubt that in the past, generally speaking, South Wales had led the way in the matter of watering. There was more watering done here than in any other district of the kingdom, but still it had evidently not been sufficient to lay the dust all through to prevent explosions. Mr. Smart mentioned in the

Mr. J. Dyer Lewis.

last paragraph on page 242 the 'Following observations in sampling, especially where roads had been "flue dusted."' Mr. Dyer Lewis said he did not know whether Mr. Smart meant dust from boiler flues; if so, flue dust of that nature was not allowed on account of the very sharp edges which made it unsafe for people to breathe in such an atmosphere. Mr. Smart had gone very fully into the methods which he suggested for the collection of the dust, and to a very great extent he (Mr. Lewis) approved of the way in which he had collected the various samples and the little instruments and outfits which had been arranged for the purpose. Mr. Lewis added that he had occasion last year to collect a sample of dust where an explosion had occurred, but which was stopped. A very careful sample was taken over about seventy yards, and analysis proved that there was too much non-combustible dust to carry on the explosion. It certainly was initiated by fire damp, but there was not sufficient coal dust in the vicinity to carry it on. This non-combustible dust about the roads was blown at least 350 yards from the place where the explosion was initiated. Witnesses declared that the dust was very fine, and it was described as of a whitish nature. He thought this pointed to the fact that where it was possible to get a 50 per cent. mixture it rendered coal dust harmless; at any rate as far as that explosion was concerned, the propagation was prevented by non-combustible dust.

Mr. R. C. Smart.

Mr. R. C. SMART: Before replying to the various points raised in the discussion, the writer would like to thank the members who have contributed remarks for the information and help they have given with reference to sampling. He would also thank Professor Moss for the congratulatory references made to the paper at the beginning of his (Professor Moss') contribution to the discussion.

Mr. R. C. Smart.

An important point is raised by the President where he puts forward the suggestion that sampling at certain points may be required oftener than monthly, and might be classified with Mr. Budge's remark *re* 'points characterised by abnormal dust deposits.'

Such points, therefore, would require more vigorous stone dusting to ensure safety.

He regrets that he omitted Mr. Budge's paper on Stone Dusting, read in 1916, from the list of methods of sampling, for in that Mr. Budge mentions sweeping strips of roadways and face.

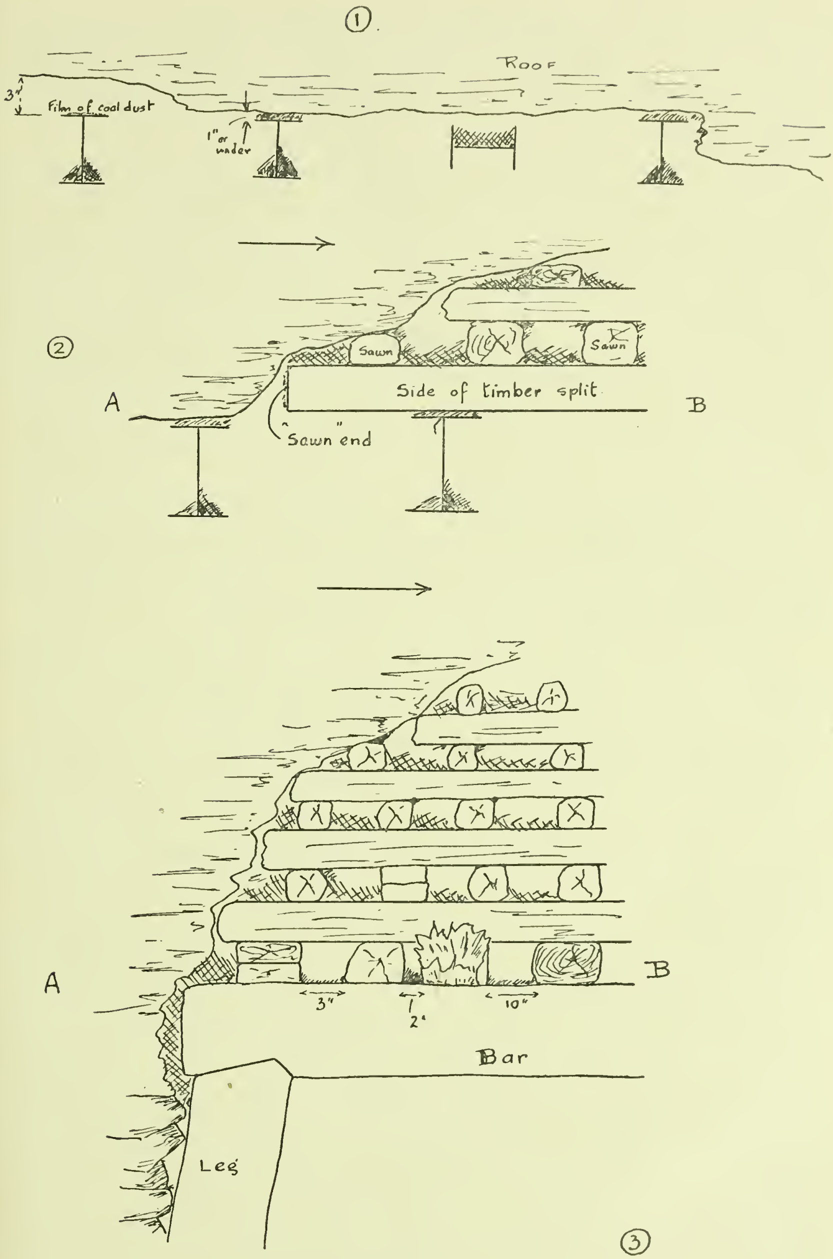
In answering Professor Moss' third query the writer will consider the rationale of coal dust deposits at some length, in order to show how difficult it is to estimate the area swept in removing dust samples.

Roof of Roadways.—The tender nature or otherwise of the roof of individual seams and the type of supports required for same (heavily timbered, girdered and chocks for filling large cavities) cause innumerable eddy currents and vortices, resulting in multitudinous variations in the dust deposits in every yard of roadway.

The following figures, which are self-explanatory, deal with roof conditions only. Direction of air currents shown by arrow; shaded black patches represent coal dust.

From reference to Fig. 1 it is seen that where the upper portion or flat top of an I section girder is more than an inch or so from the roof a thin film of coal dust only exists. If the girder is nearer to the roof than this, the space between becomes choked with a dense accumulation of coal dust.

It is noticeable that more dust exists on the surface of sawn timber (Fig. 2) than on the face of timber which has its woody fibres exposed by being split along the grain of the timber.


1
Roof
3"
Film of coal dust
1" or under
2
Sawn
Sawn
Side of timber split
A
B
Sawn end
A
B
3"
2"
10"
Bar
Leg
3

FIGS. 1–3.

Mr. R. C. Smart.

The surfaces so exposed of the smooth ligno-cellulosic walls containing the woody substance, together with the hardened surface of the resin present, do not appear so adaptable to dust accumulation.

Fig. 3 is part of the cross-section of a large cavity facing in-bye. The whole of area above A B in Figs. 2 and 3 is heavily charged with coal dust and small broken material which had fallen subsequent to timbering. Heavier deposits are noted at the ends of bars (Fig. 3) and over bars where laggings are about 2 inches or less apart (see Fig. 3). Where laggings are 6 inches apart a comparatively thin film of dust is usually found.

Where bars are closely set a greater accumulation of dust is found, of course. In the present case the writer found the maximum accumulation of coal dust within a distance of 200 yards from the bottom of downcast shafts.

Sides and Floor of Roadways.—In general the coal dust exists in the greatest concentration where the sides consist of stone packs forming innumerable interstices.

From the foregoing remarks it appears to be more practicable to take equal volumes in sampling, rather than sweeping equal units of superficial area, due to the difficulty in estimating areas swept.

Usually 70 per cent. of the dust on haulage roads passing a 28-mesh sieve is found on the roof and sides. Therefore, by the volumetric method of sampling, the quantity of dust taken at each point should be in proportion to the amount existent on the roof, sides, and floor. Otherwise, by taking equal volumes from these places an inaccurate sample is easily obtained. A parallel case is that of sampling in a return airway with a coal top and sides (for example, in the shaft pillar). The coal 'rashes' off and the bulk of dust is on the floor—hence the volumetric method would again be at fault.

Mr. R. C. Smart.

The inaccuracy would be further emphasised in a haulage road where the floor is systematically watered and ballasted to consolidated pavement for sleepers, etc. Where the floor is not watered the volumetric method would tend to become more accurate. To obtain accurate sampling by this method one would first have to determine the relative amounts of dust present on floor, roof, and sides by sweeping complete sections of roadway. Having done this, one would then take the correct proportion of dust from the floor, the roof, and the sides. This process of double sampling would have to be done at each sampling point, due to the continual variation in the proportion of dust found on floor, roof, and sides.

The only reasonable solution—and that has serious disadvantages—is the method proposed by R. W. Anderson (p. 243) of placing at intervals flat sheets of tin or smoothly planed timber, one square foot in area, in the roof and sides for the collection of dust.

A serious objection is that the samples on the collecting plates can be very easily tampered with, and unless a very large number of plates are employed it would be difficult to secure a representative sample.

Also practical difficulties of mining militate very considerably against their practical employment. Mr. J. Ivon Graham focusses the whole matter clearly when he says : ‘ if haphazard samples are taken without paying due regard to the *relative* amounts of dust lying on the floor, roof, and sides respectively. . . .’ The writer has italicised the word ‘ relative.’ In sweeping complete sections as described in the paper, the limit to the accuracy of sampling is the degree to which all the fine dust in cavities is obtained. The time taken in obtaining one sample (*i.e.*, from ten points) is about four hours, and the work could be facilitated by the use of electric cap lamps when taking roof samples. The writer hopes to show

Mr. R. C. Smart.

at a later date that sampling from five points instead of ten will give accurate results and reduce the time factor by about one-half. Of course, time lost in walking to the various sampling stations cannot be avoided.

By using a 17-mesh sieve, time occupied in sieving can be materially reduced, and also if the sieve is not filled to full prior to sieving.

The wholehearted co-operation of the managing director and manager of the collieries at which the writer is assistant manager has enabled the present system of sampling to be carried out; and, as Mr. Graham says, it is one of the most necessary points, to secure maximum accuracy, to have such co-operation.

The writer is especially pleased to have Mr. Graham's remarks on sampling, as they are the result of much practical experience with the coal dust sampling problem in the South Yorkshire coal-field.

The addition of a column showing carbonate content in the analytical register, as suggested by Mr. Graham, is of importance and it will be inserted.

The figures of analyses given by Mr. Graham are very interesting, and as a supplement to them the two tables on p. 275 have been prepared.

Where ' Compare No. ' appears in the remarks column of tables, it is to be understood that, due to similarity of working conditions at these points, the comparison of results of analyses affords a direct check on the accuracy of sampling.

Two factors—shock at pit bottom when concentrating tubs or trams of coal for winding, and high velocity air currents at pit bottom sweeping over full tubs and more especially when winding—are of prime importance under conditions as observed by the writer with reference to the formation of bulk deposits of coal dust.

Mr. R. C. Smart.

TABLE. I.—*Shallow Seam.*

Endless rope haulage from Nos. 1 *to* 7 (2 *m. per hour*).

District.	Sample No.	Sampling Station.	Comb. Matter.	Moisture.	Remarks.
			Per Cent.		From Pit Bottom.
Pit bottom .	1		54·4	6·4	
N.E. main road	2	17th manhole	49·22	8·66	150 yards
,, ,,	3	58th ,,	51·71	7·79	650 ,,
,, ,,	4	10th junction	54·4	6·3	800 ,,
,, ,,	5	Out-bye N. junction	36·8	4·6	1100 ,,
,, ,,	6	New shallow fault	38·5	4·2	1700 ,,
,, ,,	7	Out-bye 15th station	40·6	5·4	1900 ,,
,, ,,	8	Cross road at 1st face road	33·5	4·4	2100 ,, Compare Nos. 9 & 10
S.E. district .	9	Cross road at 77th face road	36·9	4·1	Compare Nos. 8 & 10
N. ,, .	10	Cross road at 7th road	34·8	3·9	Compare Nos. 8 & 9
,, ,,	11	Out-bye back end station	42·7	5·4	Compare No. 7

TABLE II.—*Six Ft. Seam.*

Main and Tail haulage (6 *m. per hour*).

District.	Sample No.	Sampling Station.	Comb. Matter.	Moisture.	Remarks.
			Per Cent.		
3rd District .	12	7 yards fault	37·8	4·4	Compare No. 13
5th ,, .	13	,, ,,	41·1	5·4	
	14	Out-bye 3rd station	27·3	4·6	Compare Nos. 15 &16
	15	,, 103rd ,,	27·4	3·6	
	16	,, 5th ,,	26·6	3·6	

Mr. R. C. Smart.

The matter was clearly emphasised at one downcast shaft where no surface factors for the formation of coal dust existed, and yet at that shaft bottom the deposits were equally as characteristic as those at the shaft where the coal was actually wound half a mile away. At the first shaft, where coal was not wound, analysis of a sample taken 200 yards from shaft bottom showed

51·04	per cent.	combustible matter
5·84	,,	moisture
43·12	,,	ash

Where coal was wound at the second shaft, analysis of a sample 150 yards from shaft bottom showed

50·38	per cent.	combustible matter
4·22	,,	moisture
45·40	,,	ash

Both these analyses are comparable as regards working conditions from a point of view of checking accuracy of sampling.

As Mr. Budge points out, cavities are a nuisance, both from the point of view of sampling and from treating adequately with stone dust, this being more especially true of a cavity existing where there is not much ‘ crush ’ or side pressure, and it is likely to exist as a cavity. In seams with tender roofs, with mining at depths of 800 to 1000 yards, large cavities are usually filled up in time with fine debris from roof and sides of cavity, produced by continual ‘ crush ’ movements—that is, the interstices between the timber and rock packs in cavity become choked and consolidated.

Mr. Lewis's correction with reference to the words ‘ head and tail ’ as reading ‘ main and tail ’ is an omission in checking through proof sheets by the author. In sampling, as described in the paper, the worst possible places from the point of view

of coal dust accumulation were examined, in addition to systematic sampling of all roads from the pit bottom to the working face. In addition, the actual tonnage of coal dealt with by each road, and the duration of time over which such a tonnage had passed was known, so that every road was subjected to a critical examination. Mr. R. C. Smart.

Also, old roads, spouts, and places favourable for accumulating coal dust in and around shaft pillars and the pit bottoms were examined.

For example, Sample No. 8, Table I, is a cross road which daily deals with more coal by a considerable margin than any other cross road in that seam, and it was for that reason that it was sampled. This principle applied in taking all samples, in order to find the most dangerous points in the roads underground.

The results of analyses showed that, except in a few cases, the subsidiary roads were well over the 50 per cent. ash margin. Samples Nos. 8, 9, and 10, Table I, are from the worst seam mined from the point of view of producing dangerous quantities of coal dust. These samples also are from different districts several thousand yards apart.

Again, Sample No. 9, Table I, was from a cross road dealing with the maximum tonnage in the district concerned.

The length of time roads had been exposed to coal dust accumulations was known, of course. When reference was made to flue dust it was dust from boiler flues, and, as the author knew from microscopical examination, dangerous to breathe from the point of view of silicosis, etc. The flue dust, however, was some that had been spread some years ago before its danger was recognised. The date when the flue dust was last used enabled the author to give on p. 256 of paper (fourth and eighth lines from top of page) the figures with reference to the thicknesses of dust found at two shaft bottoms.

Mr. R. C. Smart.

Mr. Lewis's remarks with reference to sampling on faces and roads near the working face when conveyors are being used are of much practical value; however, as none are being used, the point did not come under the author's notice.

Particular attention was given in sampling return airways and roads concerned where coal cutters are in use, although in the cases under observation the machines were cutting in dirt bands, and analyses from various seams close to working face (return side) showed from 24 to 32 per cent. combustible matter, the average being 27 per cent.

The case mentioned by Mr. Lewis was only another confirmation of Dr. Wheeler's experiments at Eskmeals, and possessed the additional value of being in such a condition after the fire-damp explosion as to be adequately and carefully examined by means of accurate sampling and analysis.

Prior to stone dusting in a dry and dusty main return airway that was not watered or naturally damp, a length of 100 yards was taken and thoroughly swept.

That is, the sweeping was done by samplers with coal dust sampling outfit as described in paper, and amounted to the sampling of a continuous length of a hundred yards.

The floor dust, dust from the roof, and dust from the sides was collected separately in sections, and after reduction with sampling shovels sieved through the 28-mesh sieve.

The following figures expressed as percentages were obtained and show the relative proportions of dust on the floor, roof, and sides :

Floor	40	per cent.
Roof	75	,,
Sides	100	,,

The road was normal in every respect as regards timbering, *i.e.*, top 'lagged' over bars or girders with occasional timber

filled cavities—the whole of the roof being timbered in the 100 yards length. The sides were well built stone packs. Mr. R. C. Smart.

In another return which was in coal pillars the above proportions would be reversed. Due to coal top or roof and coal sides 'rashing,' relative proportions of dust would be :

Floor . . .	100 per cent.
Roof	10 ,,
Sides	25 ,,

On main haulage roads where the floor can be consolidated by the usual water binding methods the proportions would be :

Floor	5 up to 20 per cent.
Roof	75 per cent.
Side	100 ,,

Where roads are thoroughly damped daily by being properly watered and not 'flooded,' the lower figure of 5 per cent. for floor dust would obtain.

The President. The PRESIDENT, in closing the discussion, said the paper had given rise to some useful discussion, and a vote of thanks was accorded to Mr. Smart for bringing this interesting and opportune subject before the Institute.

The PRESIDENT then called upon Mr. J. Drummond Paton to give the paper written by him and Professor George Knox on 'Hydraulic Stowing.'

HYDRAULIC STOWING.

By Professor George Knox, F.G.S., M.I.Min.E., and
J. Drummond Paton, M.I.Min.E., A.M.I.E.E.

HYDRAULIC STOWING.

By Professor George Knox, F.G.S., M.I.Min.E., and
J. Drummond Paton, M.I.Min.E., A.M.I.E.E.

Introduction.

Mr. Drummond Paton introduced the paper by means of lantern slides illustrating some of the installations already in operation. He prefaced his remarks by saying how pleased he was to have the privilege of coming before them at Cardiff and of appearing on the same platform as Principal Knox, his old instructor, to whom he was indebted for his early mining engineering training, and for the influence that caused him to take up this important subject.

Among the many problems resulting from deep mining operations, subsidence of the overlying rocks producing excessive squeeze on the roofs of underground workings is one of great importance to mining engineers.

On account of the increased cost of sinking and equipping deep shafts for the extraction of coal increasingly larger areas have to be worked from individual shafts, necessitating longer roadways being kept open through large areas of gob and for much longer periods than was formerly necessary.

This increase in pressure on the roof strata in the worked area results in a largely increased cost for upkeep of roadways unless a very efficient system of packing is provided. Where great lengths of face have to be kept open for the production of large outputs, particularly in districts where the coal is

mechanically cut and conveyed, efficient packing is of primary importance in reducing the cost for temporary supports and to enable mechanical haulage to be carried up as close to the working face as possible.

When an excavation is made underground by the removal of a layer of coal two potential forces are liberated.

One of these forces due to gravity acts vertically downwards at an approximate pressure of 1 lb. per square inch per foot in depth; the other is acting horizontally and is projected against the former in a direction opposite to that of the workings forming the excavation.

It has been frequently noted that when the vertical force is allowed to act rapidly the strata forming the 'nether' roof breaks through in the form of small slip faults with a maximum amount of subsidence and the angle of pull is only a few degrees from the vertical.

If, on the other hand, the vertical mass subsides slowly without fracturing the 'nether' roof, the angle of pull is increased and the subsidence reduced.

As the two forces referred to are acting towards the excavated area, forming planes of strain sloping forward beyond the solid face of the workings, it is evident that the ratio of vertical to horizontal movement produced determines the angle of pull. If the subsidence is a maximum, the angle of pull will be a minimum, and *vice versâ*, because the greater the area of subsiding surface for a given area of excavation the less vertical subsidence must there be.

In the South Wales and Monmouthshire coal-field there is another factor besides that of the ordinary pressure of the overlying strata which undoubtedly assists in bringing about excessive squeeze in underground workings.

The valleys in which the bulk of the collieries have been sunk have been cut out to a considerable depth, leaving on both

sides large masses of rock forming the flanks of mountain ranges, as shown in Fig. 1.

This leaves a large weight of unbalanced or 'unbridged' strata, which if disturbed by subsidence is free to exert an enormous pressure along lines parallel to the valleys. To make matters more complicated, many of the South Wales and Monmouthshire valleys have been cut out more or less parallel to fault planes, and these natural planes of fracture materially assist subsiding movements in exerting still further pressure.

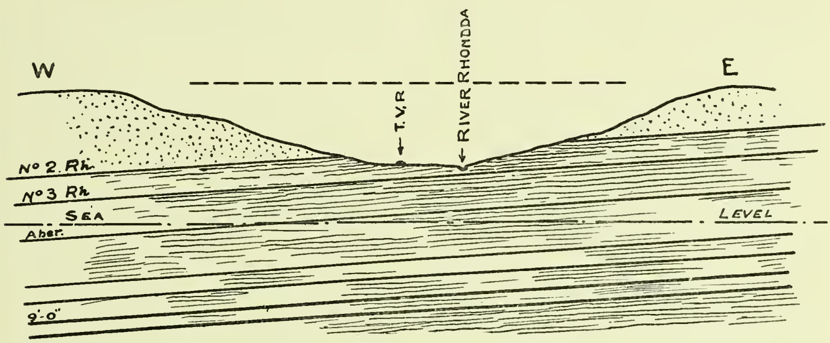


FIG. 1.—SECTION AT PONT RHONDDA.

The hard Pennant Rocks forming the plateaus of these mountains have in many cases been badly fractured by the extraction of the Rhondda and the upper seams of the Lower Shale Series from levels driven into the mountain side.

Where these workings have been imperfectly packed subsidence has resulted in the production of large fractures through the Pennants, which still further contributes to the ultimate squeeze exerted when working the deeper seams.

The effects of subsidence are most damaging in urban districts such as the South Wales valleys, most of which are densely populated and form the chief avenue for all kinds of transport in the district.

The damage to house property, railways, roadways, tramlines, gas, water, and sewage mains, etc., amounts to a very large sum annually, most of which could be avoided by a more complete system of packing such as might be effected by hydraulic stowing.

History of Hydraulic Packing.

The first recorded instance of hydraulic packing was quite accidental and was the result of the flooding of a tributary of the River Dee near Hawarden in Cheshire (Gladstone Estate —Jas. Hampson, manager), which washed large quantities of sand into mine workings (Mare Hey Pit) and caused their abandonment.

In re-opening these workings some time afterwards it was discovered that the sand had become solidified to such an extent that it afforded adequate support to the roof and permitted the adjacent coal being extracted in the pillars.

New roads were made through the pillars, which were ultimately extracted.

Its first use in the United States of America was to extinguish a gob fire in the Buck Ridge Slope, near Shamokin, Pa., by John Veith, General Inside Superintendent of the Philadelphia and Reading Coal and Iron Co., in 1884.*

In 1886 it was used by F. Pardee at the Laurel Hill Colliery, Hazleton, Pa., to support or control the overlying strata to stop a squeeze which threatened the slop.

Its first use on an extensive scale was at the Kohinoor Colliery, Shenandoah, Pa., in the Mammoth Seam, 40 to 60 feet thick at a depth of 400 feet from the surface.

It was not, however, until 1901 that the first modern equip-

* *Colliery Engineer*, Vol. 33, p. 537.

ment on a large and economic scale was erected by Berrygrat Willigar at the Myslowitz Mine in Upper Silesia.

Since then the system has been adopted and continuously improved in other Austrian, German, Belgian, and French mines, until this system of packing has become a generally accepted practice in modern mining engineering.

In 1910 it was introduced into the gold mines on the Rand at the Village Main gold mine, and is now in use at many of the largest mines.

It has been adopted in Australia, Spain, Russia, Poland, and China, but no extensive application has yet been made in this country.

A small installation has been worked by the Wishaw Coal Mining Company, Motherwell, and a still smaller installation at the Crowgarth Iron Ore Mine, also at Wemyss Colliery in Fife, and a plant is being put in in Lancashire at the present time.

In the early stage of the development of hydraulic packing ordinary cast-iron pipes were used to convey the packing material and water into the workings, but the rapid internal wear caused by the grinding action of the packing (particularly in the horizontal pipes) led to the use of linings.

At first hard wood linings were used, but except in the case of sand packing as in the Transvaal these were not satisfactory as they wore out very rapidly and required very large diameter pipes for large volumes of packing material. Mild ungalvanised steel pipes were then tried, but these also had to be frequently renewed when unlined.

The three types of pipe line now in use are :

1. Mild steel or cast-iron pipes with steel lining (Fig. 2).
2. Steel pipes lined with porcelain (Fig. 3).
3. Oval-shaped linings on the narrow or underside (Fig. 4).

Porcelain pipes are estimated to pass 180,000 to 200,000 tons of stowing material before requiring renewal, and iron or

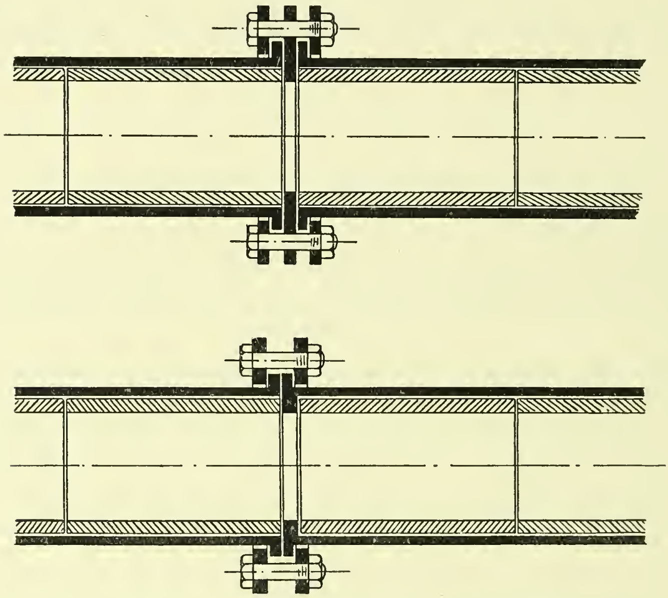


Fig. 2.—Mild Steel or Cast-Iron Pipes with Steel Lining.

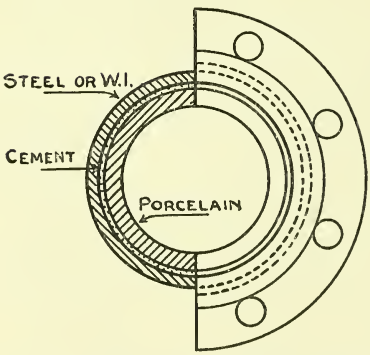


Fig. 3.—Steel Pipes Lined with Porcelain.

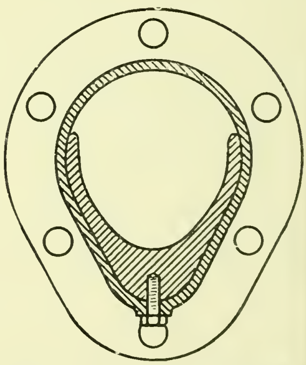


Fig. 4.—Oval-Shaped Linings on the Narrow or Underside.

steel lined oval pipes will pass 200,000 to 1,400,000 tons of packing material per inch wear of linings.

Advantages due to Hydraulic Stowing.

The advantages claimed for hydraulic stowing in Westphalia, according to the report of the British Consul-General,* are as follows :

‘ 1. The increase of the total coal output per annum, owing to the advantages enumerated in paragraphs 2 to 10.

‘ 2. The reductions under given circumstances in the consumption of pit-timber.

‘ 3. The effective prevention of underground gob-fires and the great dangers connected therewith.

‘ 4. The favourable action against the dangers of fire-damp, as all vacuities in, or in direct communication with, the goaf are filled.

‘ 5. The possibility of winning coal out of lower seams without injuriously affecting those above, and the consequently increased elasticity as to the disposition of work.

‘ 6. The remarkable much-needed power of concentration of the work, the increase of powers of production, the reduction of fore-winding operations and the facilities of bringing a new winning rapidly into full production.

‘ 7. The reduction of losses in working the broken, the saving to the nation of enormous quantities of mineral wealth, the winning of deposits which were formerly considered lost, having to be left as pillars.

‘ 8. A thorough securing of the surface against damage, through good execution of work.

‘ 9. The reduction to a minimum of the danger to life and limb in the falling of stone and coal.

‘ 10. The great advantage of the system is that it brings with it no new dangers, and *that it obviates* many dangers and accidents.’

* *Report for 1910* (Cd. 5465–118), p. 24.

There is no district in the British coal-fields in which the advantages of hydraulic stowing would be more beneficial than in the South Wales coal-field.

In getting a larger amount of permanent support in the gob the squeeze of the overlying rocks would be more evenly distributed, thereby increasing the safety from falls of roof and sides, and reducing the high cost of initial timbering and the subsequent repair work.

The ventilation is also improved owing to the reduction of leakage through open packs and the filling up of old, disused roadways; but the greatest advantage would probably be the lessening of the risk of explosion.

There would be a minimum number of places where methane could collect and produce an explosive mixture, but a still greater advantage would be the reduction in the amount of coal dust made at the face, and the amount transported into the atmosphere beyond the face.

Where narrow drivages have to be made in advance of the working face (where coal cutters or conveyors are used) the crush on the coal is shown to be excessive for a distance sometimes of several yards in advance, thus fracturing the coal.

In these fractures large quantities of coal dust are produced which is liberated when the coal is removed sometimes in sufficient quantities to convert the atmosphere at the face into an explosive mixture.

Much of this dust would be prevented if the packing behind was more complete and the plane of fracture of the overlying strata thrown as far forward over the solid coal as possible.

With hydraulic packing resulting in a reduced roof weight, which regularly applied over wide areas does not tend to fracture the roof, it is possible to completely line the main roads with ferro-concrete.

If this could be done our greatest problem in the South

Wales steam coal collieries (viz., coal dust deposits) could be easily solved by a system of watering on the roadways, which combined with the partial laying of dust on the face would do more to render these mines safe than could be accomplished by any system of stone-dusting.

Under the present system of packing enormous quantities of timber have to be used to keep the roadways and working faces of the South Wales mines in as safe a working condition as possible.

Despite this and the application of regulations involving systematic timbering, accidents from falls of roof and sides form nearly 50 per cent. of the total fatal accidents and over 30 per cent. of the non-fatal accidents in mines every year.

As subsidence is the cause producing the need for roof supports the better regulation of subsidence would naturally appear to be the best way of attacking this problem, and the saving effected in the cost of timber would go a long way towards the cost of applying hydraulic stowing if it could be shown that this process does effect better regulation of the subsiding strata.

Where hydraulic packing is in use no coal barriers need be left, as a continuous pack of flushed material would serve the same purpose.

Neither is it necessary to leave ordinary pillars of support for surface property, railways, canals, etc., thereby effecting a large saving in the loss of valuable minerals.

Hydraulic packing, for which so many advantages can be claimed, can be applied to the working of any kind of mineral and to almost every method of working them.

In its practical application there are many difficulties to be overcome, but surely British engineers are quite as capable of overcoming these as their colleagues on the Continent have been, and they have the further advantage of making use of

the long years of pioneering experience already gained in its application.

The writers feel certain that many colliery engineers, could they find it convenient to visit some of the continental mines where modern packing installations are in use, would more readily realise its importance as a part of every large modern colliery equipment.

Installations in Use.

With regard to the extent to which the hydraulic-stowing system has been applied, it would practically take up the whole of the paper available for this lecture to give the main details and locations of the installations now in use on the Continent. The writers have in their possession a list of fifty plants or more using only one type of pipe as applied to all kinds of mines established in Austria, Germany, and the general continental mining areas. Figures which were available before the war went to show that there was roughly about 150 miles of the ordinary plain pipe and the Momenertz system and 150 miles of the Stephan Froelich system.

Naturally one is averse to refer to these countries, and illustrate what they would wish to be applied in their own homeland, under the present conditions, but we will have to consider many more uncomfortable things and face difficulties apart from our past mistakes.

In casually reading through the engineering paper of the General Electrical Company of Schenectady, the description was given of a huge new mining installation in a Chinese mine. One usually associates these countries with a crude basis of mining engineering, but when one realises that the head gear, winding gear, the electrical installation, and every complete item of this plant was of the most perfect design and con-

struction, we will be pardoned for commenting on the fact that a reference was made to the method of working, and in this it was simply stated that the stowing system was adopted. No further comment was made, and the matter was passed over as an item of daily occurrence. One is therefore forced to look in other countries for installations and examples of its

Fig. 5.—Stowing-material Quarry in Silesia.

application, and while the origin of this system was in this country and was first conceived for application in England, it is one of the tragedies of the situation that we have to travel abroad and particularly into enemy areas to find examples of its application.

From the illustrations you will note that Poland, Galicia, Silesia, and other areas (not usually associated in the British mind with the best modern mining tackle) are the actual fields from which illustrations have been brought, and it is worthy of comment that we find plants and head gears to denote a

high-grade form of engineering which one must appreciate, and then realise that in this section this latter innovation is utilised.

Possibly from amongst the illustrations of plants which have been given herewith the one outstanding installation of special pre-eminence is the huge installation at Koenigen

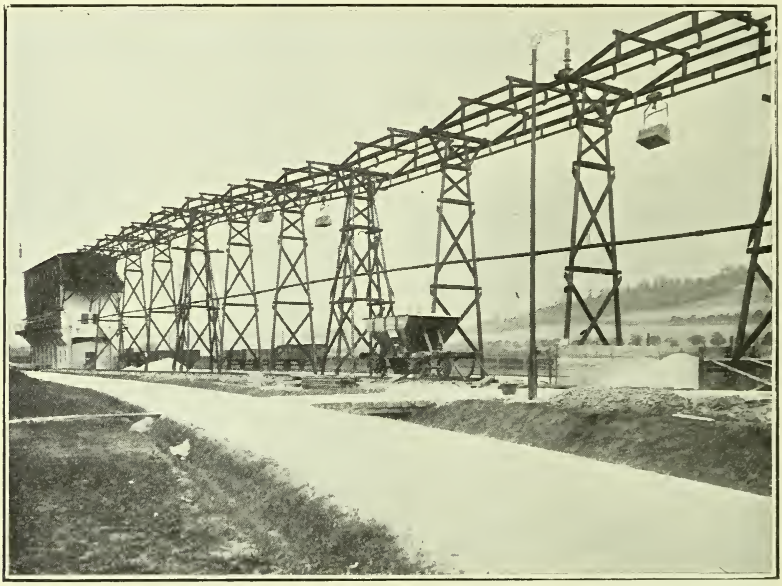


Fig. 6.—Aërial System with Storage House and Loading Silos for sending Stowing-material in Wagons to Various Mines.

Louise in Silesia. Details of this plant have been given previously in some of the writer's former papers (see *Transactions of the Institution of Mining Engineers*, Vol. XLVII., Part 4, pp. 468–505, Manchester Geological and Mining Society), and it may also be of interest to some of you to know that even in the early stages of development an Englishman had actually a fair amount to do with the installation and operation. Like the writers of this paper, he has for many years pleaded for action to be taken, and we would particularly refer you to a paper which was previously given by Mr. Gullachsen,

formerly of the Rand Mine System of Africa, on this particular subject.

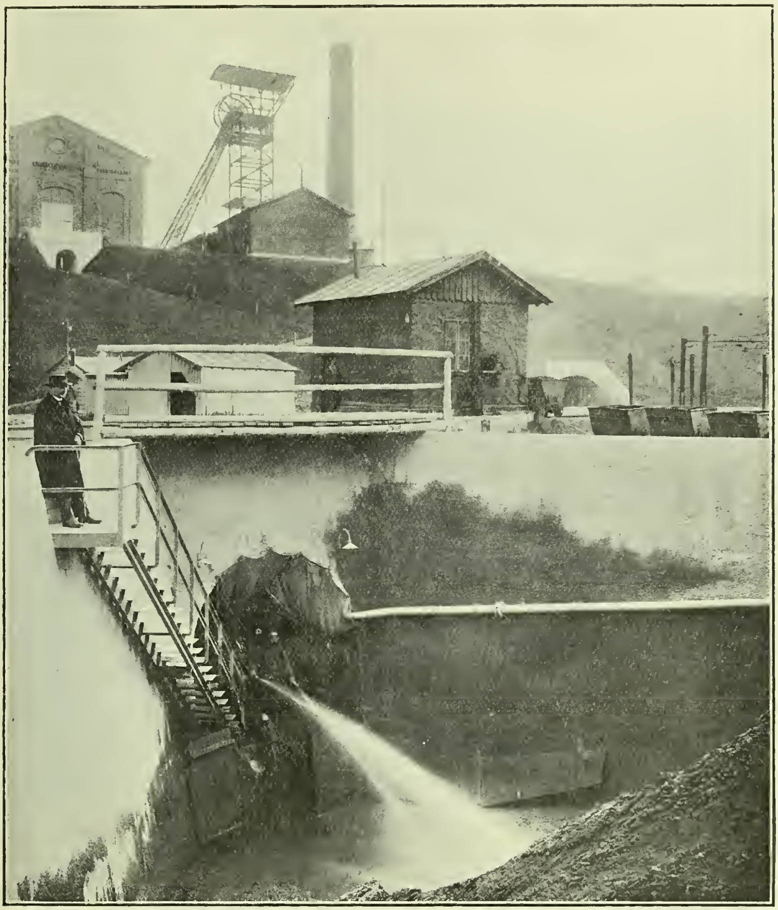


Fig. 7.—Reinforced-concrete Hopper, into which Stowing is discharged and flushed down with Jets. Note the Grid down which Water and Grit passes to the Mine.

General Description of Stowing Plant.

In presenting a matter in which one wishes a community to take an interest, it is sometimes difficult to select the field which will most particularly appeal to the local mind. Con-

sequently, if one starts with a description of some of the huge plants, the first objection is the question of cost ; but one must realise that if a larger plant has been installed, it must have been installed as the result of past experience, and when we tell you that in one large continental engineering works on the eve of the war one company had approximately fourteen hydraulic-stowing plants on order, varying from 500 tons to 2000 per day, you will appreciate that this section of mining engineering has come to stay on the Continent.

Possibly, therefore, it will be best to start with one of the simplest installations which it has been possible for one of the writers to see. Take, for example, the Hamilton plant using washery dirt for filling up under the Clyde. In this case a most simple installation, using the old tip with a plain round cast-iron pipe and a simple crushing and riddling method, has been applied, and has been the pioneer of the large later installation. For further details see paper (Vol. XLVII., Part 4, pp. 468–505, Manchester Geological and Mining Society).

This installation was erected with a view to recovering several stoops of coal which had been left under the Clyde and drowned out by an inrush of water. Further removal would have brought in more water, but by means of barricading off with stowed walls and a correct system of removal and stowing, the whole of the remaining coal was being successfully extracted and (on the writer's visit) at a cost which was exceedingly reasonable. In this, as in various other systems in different countries, the best principle is for one to strike a balance between the installation and the value of the material to be recovered, quantities to be stowed, etc., but the operation is identical in every case, and is illustrated by the slides with the details under which the material is sent into the mine. The

entire operation is practically controlled by the ‘ pitch of the note ’ emitted from the pipe. After a short time the operator becomes acquainted with the ‘ pitch ’ or ‘ note ’ of the system when working at its maximum efficiency ; this is generally a clear sharp ‘ hissing ’ sound, and on the immediate occurrence

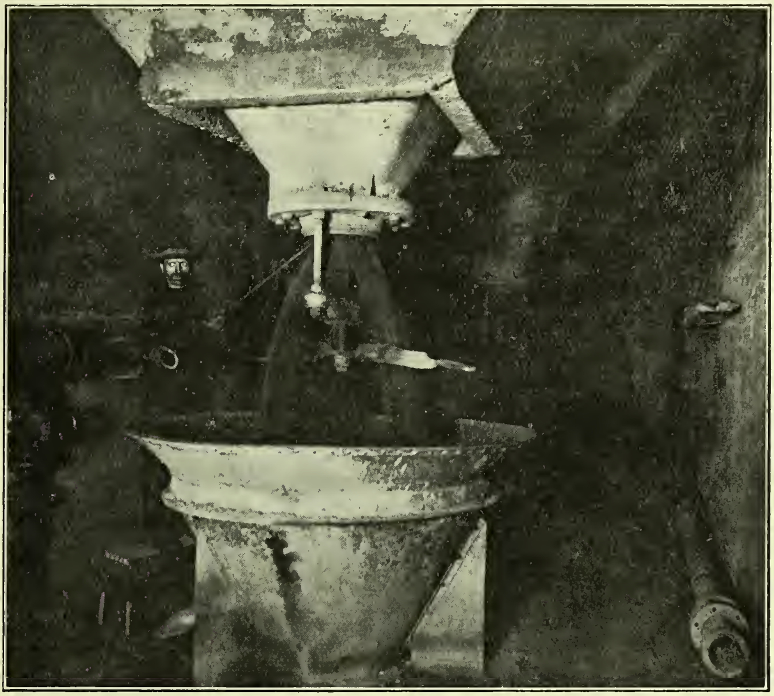


Fig. 8.—Flushing Hopper and Attendant Regulating the Feed.

of any gurgling or deeper pitch note the quantity of sand for filling is shut down and an increment of water is applied; by the increment of water the pitch of the note is immediately raised and any sluggishness of transport is avoided and the operative conditions are re-established.

The sensations that one experiences at the other end of the line during stowing are rather more alarming, and on the first occasion when one of the writers watched a stowing process

in progress he was inclined to think that the upper strata was loosening, and that his number was possibly being handed in for his return to town. The roar of the water, the explosions from the air as it enters into the goaf, and a few other sounds which have unaccountable formations are rather ' hair-raising ' at the time, especially in a deep mine where you have a heavy pressure along your line and consequently a violent relief of air at the exit of the line. Eventually one sees the mass of heavy sludge running out into the darkness of the goaf, and in a few minutes there is probably a miniature stream passing the feet of fillers still continuing in their filling operations while stowing proceeds. Eventually, after a given time, the water ceases and matters again become quiet; there is a trickling sound, and on examination we find a solid mass of material which has filled up the goaf, and very probably on the outside of the filler screen very, very slight traces of water passing back to the shaft.

Of course the whole of these conditions have to be considered in relation to the nature of the roof and the floor, the nature of the material which is available for stowing, and numerous other local conditions which must be considered. Normally, one is anxious to get a fairly loose porous gravel, if possible, for stowing material, and for this purpose blast furnace slack, crushed small light rock, boiler ashes, washery refuse from the pit which will not levigate or become ' clayey ' easily, and similar structures of material are ideal. The quantity of water necessary to convey individual classes of material is also determined by the character of the pipe, gradient, depth, etc.; it may run as high as three or four to one, and occasionally as low as one to one, or in some cases slightly less, as in special cases in Saxony and Silesia, where air has also been used to augment the water transport.

In passing, it may be of interest to note that this same

material after it has been in the mine for a short period becomes as hard as a parent rock, and in some cases when blasted out where a road has had to be cut in a stowed portion of the mine it has been the privilege of both of the writers to see statues and emblems of the German Mining Engineering Associations carved from blocks of this material. In some cases, where the stowing plant and the mine are near the sea, it has been possible to use sand, and in fact it is used and quite frequently applied.

From a general investigation of the bulk rock which is mainly available in Wales for this purpose, the impression is that it will be on the hard side and rather difficult to crack to the required dimensions, but there are huge tips of old spoils, etc., which are available, and it will be a long time before these are used up for general stowing which is likely to arise for a few years. Once this system has been established in Wales, and it will have to be established if she means to mine the whole of her coal, the trouble will not be the question of stowing, but it will become, as it has become on the Continent, the question of securing stowing material. The difficulty in the mines abroad now is not the stowing system, but how to acquire sufficient material to meet the stowing demands; and it may be an item of interest to you to know that the inter-traffic system between the Rhine and the Danube was under control by administrators in such a manner that those who were carrying goods or had any form of transport along this system were forced to transport waste material in barges on the canal at a minimum rate, we believe, of a tenth of a penny per mile to the mines for stowing purposes. Consequently, when you realise that a hundred mile ton, that is, one ton for a hundred miles, if this is offered from any industrial city along this system, could be transported for a mark, approximately tenpence, you will appreciate the position of this

subject in that area. As already stated, these equipments vary from a few tons possibly per hour to some thousands of tons in the day. If the material comes to the pithead in bulk and rough form, then cracking plants as illustrated in Mr. Paton's former papers must be installed (see Fig. 9).

These consist of sizing, crushing, and re-sizing systems whereby the material is reduced from block form down to between an inch and a half and three-eighths. From the crushing plant system the material passes forward into large conical hoppers, from which it is fed into the actual regulating chute. In the tun dish of the feeder is generally arranged an upward jet of water which plays opposite the grid on to which the cinder, ashes, and stowing material are dropped. By a certain supply of water, regulated to the quantity of sand, a correct mixture is obtained, and the material passes forward. In passing down the shaft there is not the same wear of lining, as this difficulty has been overcome by directional cones which are introduced at every so many yards. These truncated cone sections give a direction to the dropping material which deflects them away from the inside of the tube, and any wear which arises takes place on these same cones. As we come towards the bottom of the shaft the pressure is naturally increased or built up, and particularly so in any case where we have a 'lock.' To meet such excessive pressure release valves are often fixed on the system to avoid excessive shock, and where the material impinges on the foot of the column a special construction has been adopted to avoid wear (see Professor Knox's paper, *Trans. Inst. M.E.*, Vol. XLIV., 1912).

Passing forward from the pit bottom one immediately comes in contact with the chief trouble in the system, that is the wearing out of the pipe where the stone or gritty material has to flow on a more or less horizontal system of pipe. In

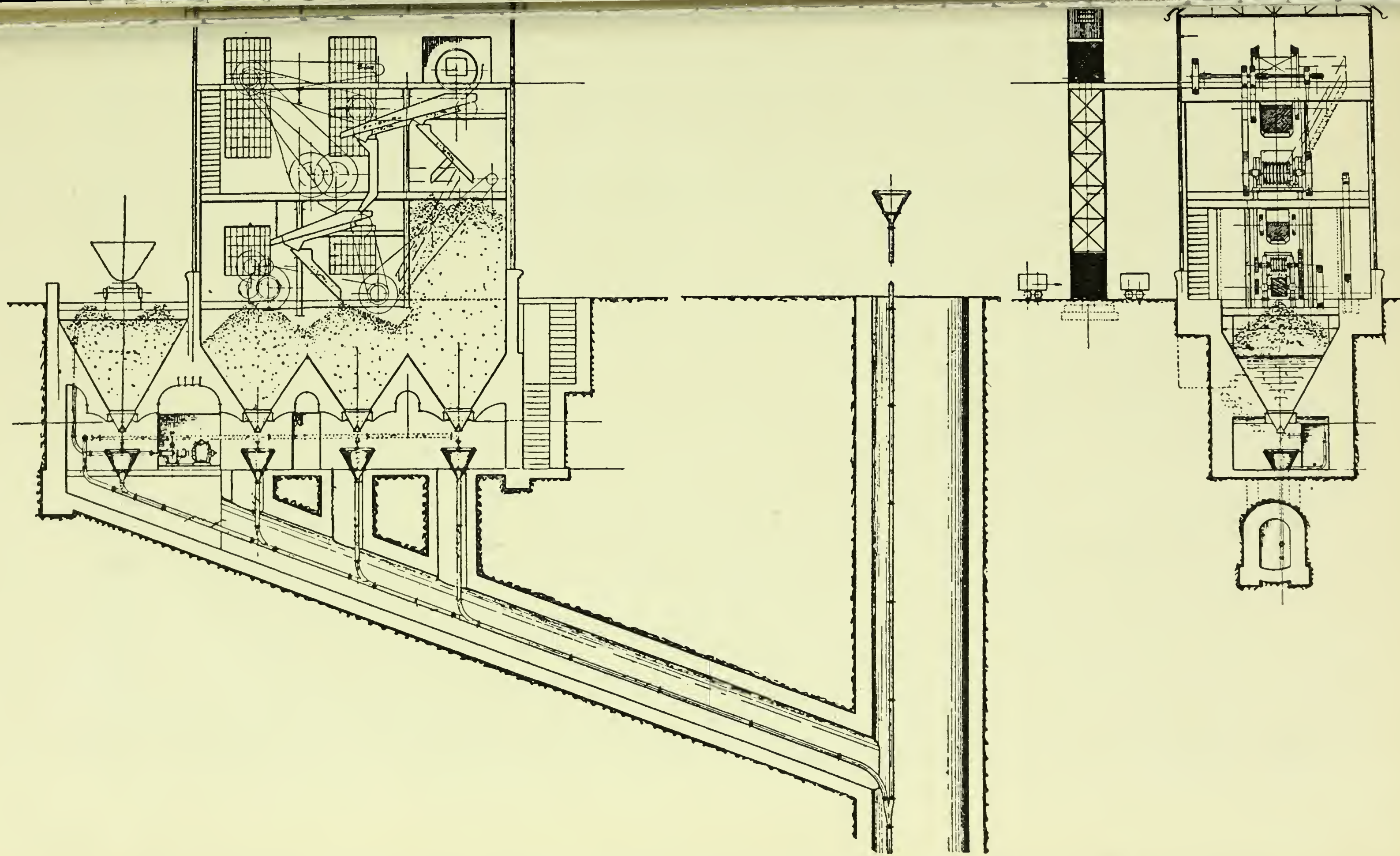


Fig. 9.—Hydraulic Stowing Plant in Russian Poland. Hourly Output of the Crushing Machines, 2,120 Cubic Feet.

view of the larger later development of plants, and the heavy wear that previously arose, Herr Mommertz developed a special system of pipe linings. Mommertz of the Deutscher Kaiser group of Hamborn conceived the idea of lining his tube with porcelain. A small tube which was prepared in that area is on show at this meeting, and the details are best realised from a personal examination. Stowing with the porcelain lining the wear was still high, particularly in cases where a hard 'gritty' material was used for the stowing. When the stowing system travelled East and became utilised in Silesia, they there had serious trouble through the excessive wear from sharp silica sands which were used on several occasions, and to be able to use this material Herr Stephan developed a special pipe. The principle of the flow in the Stephan pipe is conceived by considering a column or glass of water from which a strip could be easily removed and lifted from the side of the glass all the way down, then if we notice the manner in which the water would issue from this orifice, we would get out the basis of the flow in a Stephan type. It is quite apparent that the water will flow forward quickest at the bottom due to the hydrostatic head. Level linings, curves, rises and other features which have to be taken into consideration have been all worked out in detail, and are in the possession of the writers, and with such care has this work been done, that it is quite possible in some of the cases to get old linings which are practically worn to a uniform thickness throughout their entire structure. The lining in the Stephan pipe is made of a special high grade wearing material, and by means of such lining one can easily renew the vulnerable section of the line without general discomfort or upsetting the main system.

It is sufficient evidence of the superiority of this type of pipe lining that where an open market was concerned the

Stephan pipe was generally installed, and when one comes to consider the final overall charges, maintenance, and other features, the lined pipe seems to hold the field in preference to all others, particularly for large installations.

Arrangements at the Faces.

No standard system has yet been defined as a universal method for stowing a mine; the nature of the coal, lines of fracture, the length of the roads, etc., all determine the manner in which the coal has to be worked, and in a corresponding way the nature of the stowing system is affected. It varies from small extracts of 15 yards square to larger pillars of 200 yards square or 200 yards basis, and sometimes double that in length, and in one of the slides shown a system as presented by Mr. Paton under guidance of Professor Knox has been specially suggested for the application of the stowing system.* This system was developed under the advice of Professor Knox and was originally produced at the early stages of their joint working and investigations into this method. The details are best examined from the slides on the screen, and from the general illustrations shown you will doubtless be able to select for your own home system the methods of working which will be best suited for your own conditions. The pipe is simply laid to the district or section where stowing is in progress or where a cavity or section is being filled up, and there are no troughings or culverts necessary unless in a case of very special and unsuitable roofing or floor, where it may be necessary to install something for the conduct of the water back to the shaft to avoid damping of the floor and the consequent 'heaving' or 'lift.'

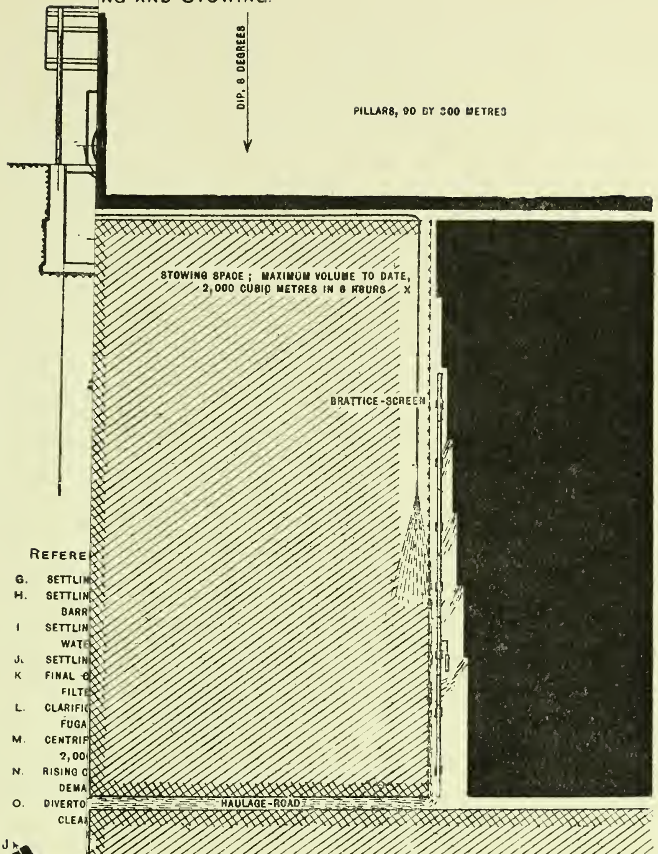
* See "Small Coal and Dust: Its Production, Prevention, Treatment, and Utilisation," by J. D. Paton, *Trans. Inst. M.E.*, 1913, vol. xlv., p. 421.

Filtration.

The details of filtration are necessarily defined by the workings whether they are new or old, and the extent to which old work or old roads may be available for settling roads and drainage. We have seen a seam in actual operation where the stowing was in progress while the filling out and the work on the coal face was proceeding as usual; the water was running down the side of the stowing wall, and for the time being the conveyor was more or less held up by reason of the amount of water on the main out road. In one particular instance in the Rhine group the stowing had hardly ceased and one was almost unable to get to the bottom of the panel before the man on the haulage road was actually getting the hutch back into position and passing the conveyor chute into it to commence filling out work. The complete circuit was made right from the stowing face down through the main drainage road, through the various old roads, and finally into settling ponds and filters. In cases where special caution is necessary these settling tanks are divided into several parts, with various filtering capacities and sections which divide them up. They are also invariably fitted in duplicate groups or according to the maximum speed of the stowing, and it is no uncommon condition that energy as high as 1000 horse-power or over must be applied to the pump which sends the water back to the surface. In the case of mines which are opening up and have no old goaf or workings where the material can be directed for settlement and filtration a special system of collecting roads and handling apparatus has to be built up into the seam (*Trans. Inst. M.E.*, Vol. XLVII., Part 4, p. 28).

It has usually been considered in this country that stowing

NG AND STOWING.



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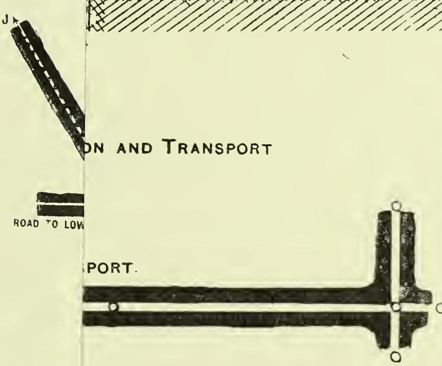

ON AND TRANSPORT

ROAD TO LOW

PORT.

TO FIGS. 6, 7, AND 8

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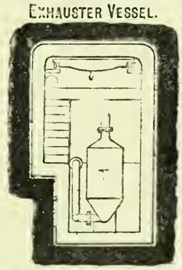

FIG. 7.—PNEUMATIC EXHAUSTER VESSEL.

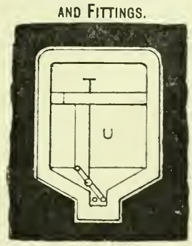

FIG. 8.—SLUDGE-TANK, AND CONTROL-VALVE AND FITTINGS.

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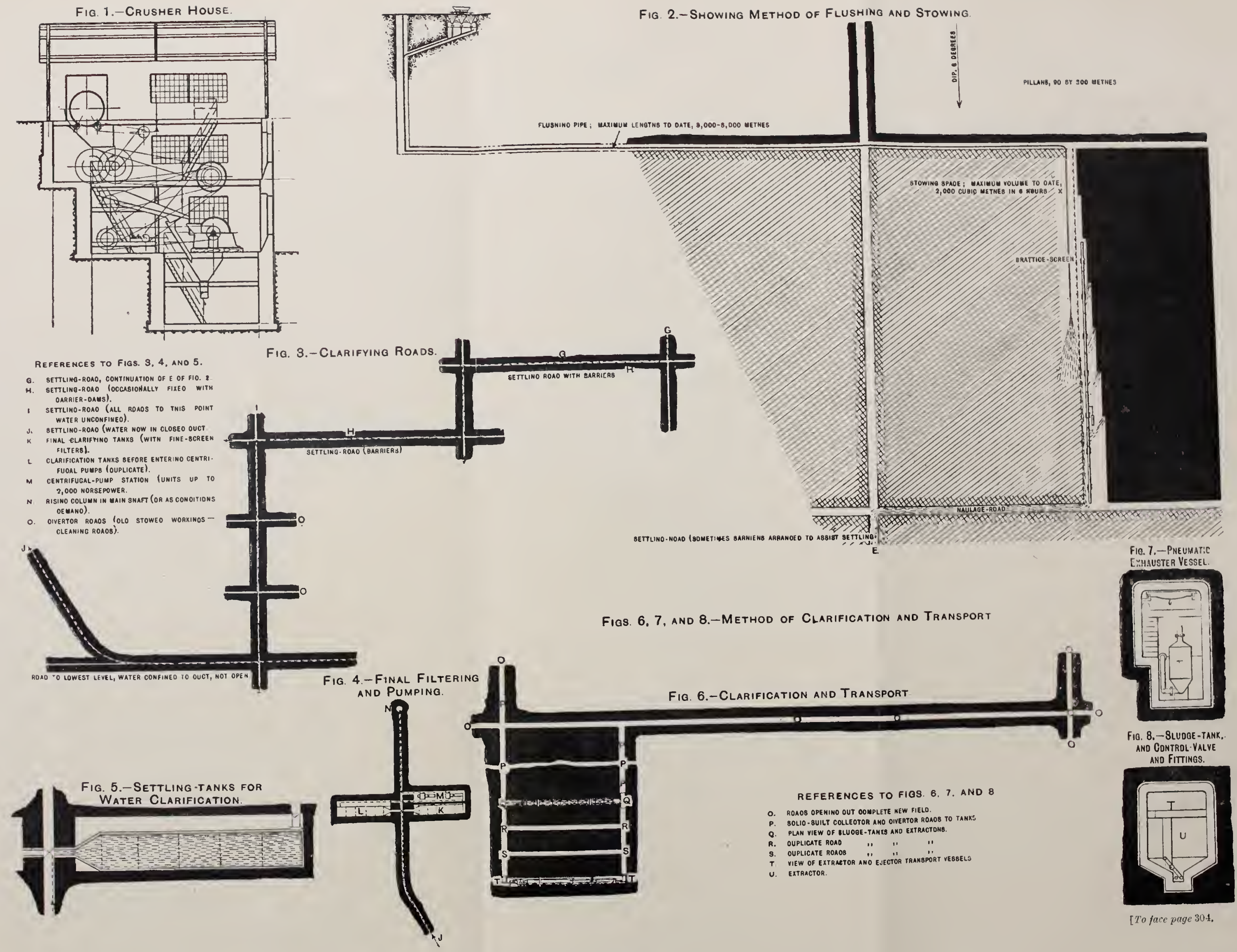

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Fig. 10.

is only necessary for seams that it is impossible to recover due to some special overhead building and feature, and it is worthy of note that in one particular instance the stowing system was installed before they commenced to extract coal in serious quantities, and as a matter of fact it would have been impossible to work this particular mine successfully without the stowing system. The seam is roughly twenty-eight feet, and is worked in three layers of three metres. The relative advance of these individual layers is so adjusted that by means of the 'squeeze' which arises in a progressive order the actual operation of coal getting is reduced to a minimum, and there is a tendency for the coal to come away quite easily in the actual getting operation. Further, there was a time in this same seam when it was impossible for the mine manager to have a comfortable night's rest. The question of night-work for him is now a thing of the past, and the organisation of his mine is such that he may rest easy and comfortably at home and not know what a gob fire means.

Objections raised Against the System in this Country.

(*a*) *Cost of Providing Special Material.*

There are in our established mining areas many large heaps which will quite satisfy the writers for a year or so to come, but the question of packing in bulk will one day arise, and in this respect some of our fields are much more favourably placed than others. In the Staffordshire fields to the northern section of the area there are the Bunter Beds, a system of rocks which is ideal, and when once concerted action has been taken by the mining industry to consider this problem seriously, we

have not the least hesitation in saying that some sensible arrangement can be come to whereby the many thousands of coal trucks which travel to your various docks and return empty will be able to be sent through some points where stowing material will be available in large quantities, and also of a suitable nature for the purpose required. The best plan is to consider the total tonnage of coal which is delivered to various areas, and also realise the many miles which your empty waggon returns, serving no other useful purpose than a 'wind transfer'; it will doubtless be possible to direct this returning empty waggon through a point where stowing material can be obtained, and we leave this to the gentlemen of your various mining companies to select your final centre, and as a guide you may refer to suggestions as defined in this paper (see map for Welsh System). See *Trans. Inst. M.E.*, Vol. XLVII., Part 4, Fig. 16.

At the present moment our corporations and cities pay so much per ton for the removal of ash and similar material; there is no need to worry about the deposit or dump for such material when we come to consider the problem of stowing for your Welsh field. Better surely to pay a little more to have your beautiful country undefiled by such material, maintain a clean hillside for the homes of your people, and regulate by the use of waste material the cleanliness of the valleys around which your songs have been written; and if in settlement it costs you a few more pounds per annum on the general charge of your national industry, even the initial cost will not exceed the final national profit.

It has been found that it will pay to crush material and even expend as high as 1*s.* 6*d.* per ton on the same, therefore what has been done abroad we claim can always be done better in Britain.

(*b*) *Cost of Maintenance of Pipe Line.*

The actual amount which is likely to be paid for maintenance in an installation is entirely a function of the characteristic of the installation ; if it is a simple inexpensive cast-iron process, as the general first trials usually are, then doubtless your wear will be high and your maintenance cost proportionately high. In discussing this point, which was raised in Staffordshire at one of Mr. Paton's lectures, he referred to a statement made by Professor Knox in regard to a number of plants which were installed in Saxony. One speaker then raised the question of the small cost in this case, and the large cost which must have been involved by some of the plants defined by Mr. Paton. The defence put up was simply this, that in the initial stages they did not care to risk an expensive plant, but once having established the process and discovered its value, they were prepared to go to huge amounts in their general and initial costs. Therefore, while in an initial trial condition one might not be prepared to put in a huge installation, they must not forget that in the long run it pays to put in good plant ; and it has certainly paid our continental competitors to put in the very finest, and to establish plants which are run on the very best plans. No man puts down large amounts of money for a 'hobby' in a commercial life, and the moral is obvious. Regarding the difficulties of packing in flat seams, there are always extreme apologists in every proposition, and consequently if it is possible to point the weak point, it is always the one which is raised by the objector.

(*c*) *Difficulty of Packing Flat Seams.*

(1) *Flat seams* certainly offer greater difficulties than those with a type of gradient which takes the water away constantly, but there are many seams which are not flat and in which gravitation effects will remove the water which is neces-

sary for the stowing process. Flat seams have therefore to have special precautions taken, and something has to be arranged as barriers in such a manner that the water will be kept away from the working face, and the overflow led to the desired point with a minimum of trouble.

Certainly, where flat seams are also accompanied by a very clayey floor, one has a difficult commission, but it is not desired that we tackle in the initial stages the most impossible conditions that are likely to arise; and when experience has been gained in a fairly normal roof and floor installation, we can progress to the difficulties of the flat seam and also the soft floor, which has already been overcome, and particularly in the case of the Koenigen Louise, Silesia. They have neither ideal gradients nor ideal strata adjoining the coal, but yet they get out 1000 tons and over from a 200-yard face in twenty-four hours, and they stow a cavity equal to 2000 tons in six hours.

(2) *Unfavourably inclined.*—There is a natural law that water will not run uphill, and it has a serious objection when forced to carry with it anything in the way of small stones on the uphill job; but on uphill conditions, with a reasonable pressure behind it, it has been quite possible to stow fine material up a 50-metre rise on a 1000-yard road. Of course, this is accomplished by a larger quantity of water, and we have a proportionate increase in our tunnels. Where the actual inclination is against the stowing system, and the field is of any extent, what is done is to 'drive in' a special tunnel or to set a small borehole to the rise point of the seam, drive up to meet it, and then set up your working accordingly. This has been done in many scores of cases with every success in our competitors' fields, and we would particularly refer you to the work and examples given by Professor Knox in regard to the work which is mentioned.

(3) *Very thin seams.*—One of the writers recently had the pleasure of meeting an eminent Belgian engineer, and in describing to him some of the coal which was yet left in England and still unmined, he asked him to compare it with the state of the Belgian fields. Were some of our Welsh people aware of Belgian conditions, and could they have seen the expression on his face, I am sure that they would be more contented and realise the power that yet lies in this old country, if we utilised the resource and power which the Creator gave to her.

We have never yet had material to tackle like the Continent, and we are only starting on it. In these other countries they have had seriously diminishing fields, especially with the Belgians, the French, and some of the Rhine fields, for the past half-generation, and this is a detail which is distinctly worthy of note in regard to the future of our fields. Every seam which we extract adds to the growing difficulties of further extraction, and as we come down on the scale and tackle our thin seams we will come to a point at which, unless a fixed stowing system is established, we will cease for ever to be able to recover our yet undeveloped resource. There is no difficulty whatever in stowing thin seams, and there is every possible advantage in the stowing system for Britain ; and in normal conditions where machines are worked with difficulty, it is a huge advantage to have your face advancing at a very rapid rate, and this can only be done where the stowing system is following closely behind your machine-cut face.

The future system of mining will be a ' machine-shop basis,' and in the particular instance already referred to where three cuts are taken off in the twenty-four hours, and the face advances 10 feet, it has only been possible to realise this by a stowing wall following the empty space at a proportionate rate. The writers have travelled many miles in thin fields about two feet or a little over this, and it is no uncommon

feature to see stowing panels of 100 to 150 yards square or 100 by 200 yards laid out in long sections for continuous extraction on the basis as already defined. Hydraulic stowing in very thin workings will make the process into a complete effort for machine mining and machine extraction.

(4) *Very thick seams.*—One of our greatest national calamities was the fact that our thick seams have very often been our finest coal, and, consequently, they were the first to be attacked. Had nature provided against the unwisdom of man in regard to his methods of stowing by placing seams over 6 feet in the category of third or fourth rate coal, we should not have had a loss of anything up to 50 per cent. of our available coal left in the mines. Hydraulic stowing in the thick seams enables every available ounce of the coal to be removed. Gob fires in a hydraulically stowed mine are an unknown quantity, and the speed of extraction and working conditions may be rendered almost ideal by the scientific application of this method. There are in this country still some fields of over 20 feet, and it is a sign of the times that some of them which may be worked are being considered in relation to the stowing method.

The Difficulties due to Creep.

The question of creep is a matter of relative surface pressure to the supporting column on which it is distributed. Every miner knows the manner in which his trouble grows as the workings open out and the supporting point becomes less and less. If one has the advantage of reconstructing strata with material which would eventually become a conglomerate, you can easily realise that the trouble which arises with tremendous concentration of pressure on one section or local point is cut out. Again, the actual manner in which the fractures arise in the upper strata has been well illustrated by

Professor Knox, and so long as the fracture takes place in a more or less horizontal line, there is little fear of surface cleavage lines being projected to the surface and an entire riding on a slip plane.

The natural characteristic which defines the tendency to creep is the levigating tendency of any material which comes in contact with the water. A simple and useful plan which ought always to be considered in regard to any strata which may be subjected to hydraulic stowing, or is under consideration for hydraulic stowing, is to take a piece of the same material and to deposit it in water, examining it, say, every three or four hours to find the extent to which it has been levigated or become plastic. If, for instance, we take a one-foot block of the floor of a mine, crush it up into the normal smaller sections, or the smallest sections in which it is likely to be broken, and submit this to water effects, the stone may have an actual time constant of three, five, seven, ten, or more days before the water penetration really starts to disintegrate the material; it may be less.

It is quite apparent that there is an advantage in a test of this constant, for if we once established a time constant of five days for a certain floor or material, and the advance made in passing ahead on this is at the rate of three to six feet in twenty-four hours, one can realise that there is not time for this creep to take place with a levigated matter, as a fresh section is always coming into consideration, and these sections under such conditions are generally protected and kept as dry as possible by means of conveying troughs which remove the water at such zones.

One must also, however (when working under difficult conditions), consider the total quantity of water which has to be passed in, and if possible diminish it by means which have now become available.

As in the case of the mines shown in Silesia, where pneumatic extraction and transport has been put in to convey as well as transport water, so in future developments will the transport of this material be considered in regard to the difficulties of the natural situation in the mines. In a case in Saxony, where very fine sand is available from a glass-grinding works, the method of transport is as follows:

The sand dust is put into a large bin, in which it is defined and mixed with a certain quantity of water, and as soon as this material is got to the right consistency a sluice gate is opened and the sludge is sent forward down the mine. Compressed air is turned on behind this, and the whole mass is pushed forward to the face. We believe that it will be possible in the future to get this efficiently applied on a ratio of one of water to one of material, or possibly something less. The question of 'lifting' arising from moisture is probably anticipated to an undue extent. You will certainly accentuate the 'creep' by the introduction of water, but you will in the latter stages of a mine counteract anything offensive which may arise through water by the introduction of a system of support which is the natural antagonist to creeping roads.

Cost of Pumping.

As the quantity of water for stowing solids must necessarily vary according to conditions, the height of stowing column, etc., so necessarily must the purchase cost be determined. There is also one further feature which has to be considered, and that is the question of levigated matter and grit which may be eventually carried forward to the pump. Modern pumps for specially handling this class of material have been brought to a high state of perfection, and it will be possible, and in fact a method has already been used, to place the pump

at the end of a section or system (see illustration of Hibernia stowing system, *Trans. Inst. M.E.*, Vol. XLVII., Part 4, p. 6), whereby the water and sludge will be removed under pressure, and will not come into contact with any of the haulage roads whatever, but will be confined to an internal tube path and delivered at the point where settling and filtration will be obtained under ideal conditions, and the water which returns to the shaft end is first of all filtered to a fair degree of purity. Again, it may not be necessary to arrange the return of the whole of the water to the pit-head. A sensible adjustment of quantity can eventually be arrived at, and it is no uncommon condition to find the same water in the upper level serving for a special stowing system for the lower seams, and so on throughout the entire mine (see Fig. 11).

Injury to the Health of Miners.

It has often been suggested that this system will cause injury to the health of the miners ; so far as the writers' experience has gone it has generally provided, instead of a distressing effect, a rather refreshing and invigorating condition. If you are near the exit from the pipe, there is invariably a big inrush of cold fresh air ; it may be slightly humid, but it is not unwholesome. If you are outside the screen, there is a flow of fresh water which reminds one of your little Welsh brooks, and for the moment the mine floor becomes a little interesting water scene. Of course, this is in mines where good floors are available; in others the water is confined ; in flat, difficult seams it may produce a rather difficult flood. But on the whole the best defence and reply to this point was made by Mr. Massmann at the discussion on Mr. Paton's paper in Manchester. Sir Thomas Holland raised the question of the action of the water in the mine, and a case was cited of the Nordstein Mine, where previous to stowing the actual temperature in the mine was

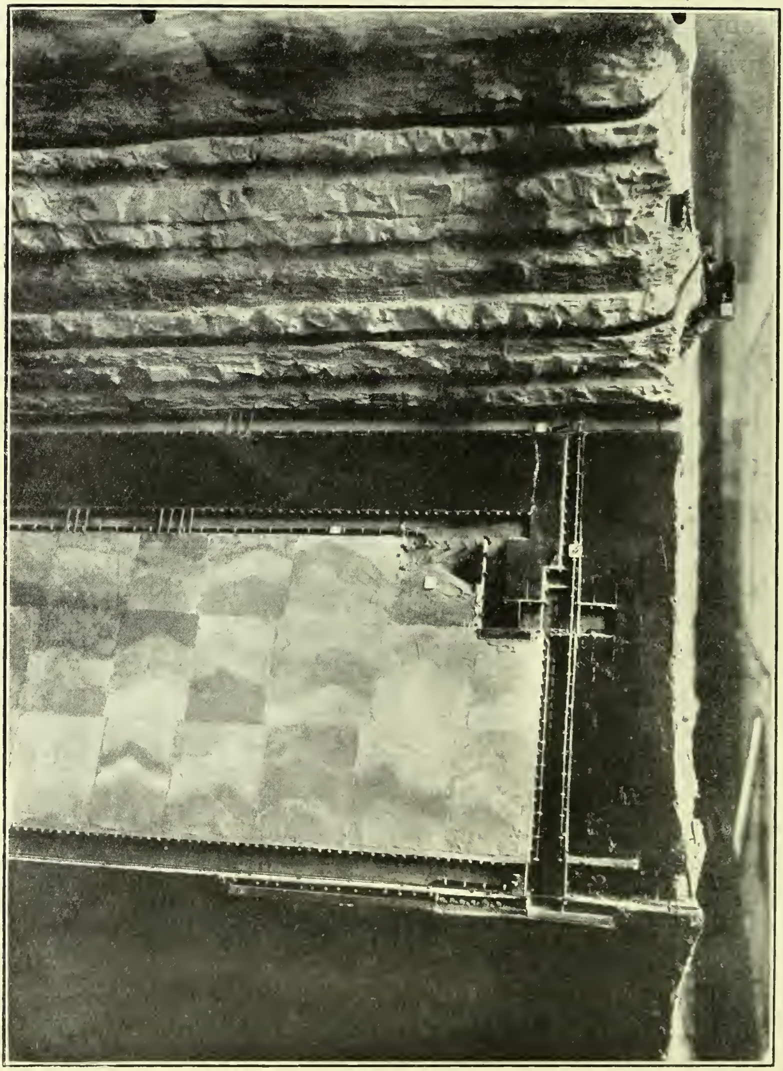


Fig. 11.—Photograph of Model showing Flushing Hopper in Mine at top Right-hand Corner, Pipes, Stowing Space, Clarification, and Pump-chamber for Water Return.

120° F., and after stowing the temperature fell to 82° F. You must realise that when a mine is stowed the air is generally taken to a point where it is wanted. In a mine which is a mass of huge caverns and 'gobs' there are many alternative paths, and 'wind' is as fickle in its behaviour as the frailer sex. Endeavour to get it down a fixed haulage road and you will find it branching off through every conceivable byway and highway throughout your mine. In a stowed mine there is one road, and that is from your pit eye to your working face and back again, consequently your fan serves its purpose and does its work for the section it was intended to supply air to. Again, you do not provide an oxidising agent for the disintegrated coal which lies in your wastes, and instead of an emission of foul gases and explosive vapours you have a little humidifying effect by the passage of a little cold water down your roadway and back to the shaft. Again, one must realise that stowing does not take place through the entire working period. If you will take the ratio of the Koenigen Louise Mines, where in twenty-four hours a thousand tons are removed on a face, and in six hours two thousand tons are stowed, you will realise the ordinary conditions under which stowing takes place and the relative time to be allowed for the various processes.

Freezing of the Pipe Line.

There may be a little trouble due to this at the pit-head and very probably further down, but normally it is not a serious trouble unless in very cold regions; also you must realise that possibly for half of the day, or at least for a few hours or so, the pipe is not filled with water at all, but is standing empty and only containing air. There is less trouble, therefore, likely to arise in a stowing system than in one of our ordinary

pump systems, and equal precautions on your stowing systems will ensure the same conditions as can be established on pumping systems.

Difficult to Apply to Existing Mines.

The pessimist in life always has the biggest bulk of trouble allocated to his own walk in life, and consequently one meets frequently a 'confession' by an ossified individual that it might be all right somewhere else, but it would not do for him. As a matter of fact, several clients went to see some continental installations. On the spot and actually watching the operations these individuals were inclined to take off their hats and admit the wonders of the whole position. As they crossed the Rhine and passed on through Charleroi the hat came further back towards the head. When they got to Lille it was very nearly back again, and when they got to Calais it was fixed hard on the back of the head. On board the ship it was discovered that there was something in an English mine which was not in the continental mine, and by the time they reached London it was finally decided that it might be all right somewhere else, but it would be of no use for their mines. The temporary flexure of their brains in a German mine could not last in our colder British atmosphere. We seem to forget that this system was not developed in new mines at its start.

Application in South Wales Mines.

There is nothing in the South Wales coal-field so vastly different to that pertaining in other countries in regard to the geological conditions of deposit—with the exception of the excessive squeeze already referred to, which is a condition requiring a maximum amount of permanent support—that would prevent the successful application of hydraulic stowing.

Soft floors, faulted ground, and irregular inclinations are to be found in the mines of both the New and the Old Continent where hydraulic stowing is now successfully applied.

In a Belgian mine visited by the writers the strata including the coal seams is so contorted that the same seam is met with in a hard heading six times in a distance of 800 yards.

Owing to this overfolding the thickness of seam on the bends is sometimes increased to five or six times the original height, whereas on the limbs it may be only one-third the usual height, yet hydraulic stowing was successfully installed to take the place of hand packing.

Method of Laying Out.

The lay out of a mine where hydraulic stowing is projected can be most satisfactorily accomplished in a new mine in the process of development, but the workings of most mines having a sufficient area of coal unworked to pay for the capital expenditure of plant required can be adapted for hydraulic stowing.

Mines worked on the pillar and stall system which have been abandoned as worked out have been re-opened and the pillars extracted by the aid of hydraulic packing.

In other cases where large areas of coal have had to be left in to protect towns, railways, etc., as at Essen, the adoption of this system of packing has permitted of all the coal being extracted, thus lengthening the life of some of the collieries in the district by 50 per cent.

As it is essential that the flow of the flushed *debris* from the surface to the pack should be downhill, the best position for the erection of the installation is at the rise end of the royalty, where a special stowing shaft may be sunk if the depth

is not too great and if suitable packing material can be obtained near (or be cheaply transported to) this point.

Where the sinking of special shafts for this work is too costly cross-measures drifts may be driven from the main shafts where the strata is highly inclined, or the roadways in the upper seams may be used to convey the material to pack the lower ones through small shafts or boreholes connecting the seams.

In laying out the workings of a mine for hydraulic stowing the method commonly adopted is to cut up the 'taking' into pillars or panels varying in size according to the thickness of the seam.

In seams over 5 feet thick where ripping for main haulage roadways and airways is not required, levels and headings (4 or 5 yards wide) are set out to form pillars up to 400 yards square.

In thick seams which have to be extracted in two or more layers smaller pillars are formed than in seams where all the coal can be worked in one layer.

The narrow drivages are made as rapidly as possible to the rise and connected to the stowing shaft, cross-drift, or other connection from which the packing material has to be conveyed, after which the extraction of the pillars or panels is commenced in the form of *wide work* faces as shown in Fig. 12.

Figs. 13 and 14 show the method adopted in working a thick seam (36 to 40 feet) in upper Silesia in two operations.

The narrow roadways are made in the bottom layer of the seam, after which the pillars are extracted towards the rise as shown.

The space behind is packed as the workings advance and the upper layer commenced in the lowest series of pillars as soon as the bottom layer is opened out in the second series.

The old roadways to the dip are used for settling ponds as soon as they are finished with for hauling purposes.

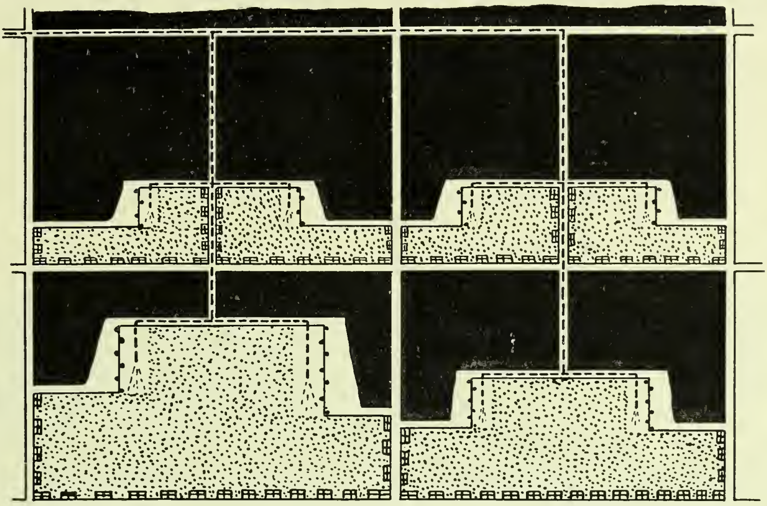
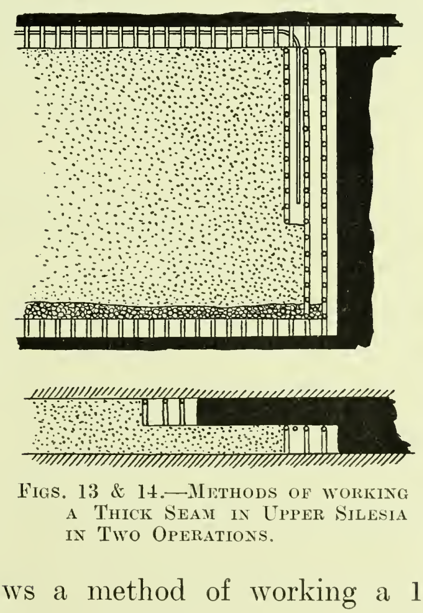


FIG. 12.—WIDE WORK FACES.



FIGS. 13 & 14.—METHODS OF WORKING A THICK SEAM IN UPPER SILESIA IN TWO OPERATIONS.

Fig. 15 shows a method of working a 12-feet seam at Tarnowitz by wide-work faces.

In both these cases prior to the adoption of hydraulic packing a large percentage of the coal was lost through heavy roof weights and gob fires when pillaring back.

In moderately thick seams (6 to 10 feet), where the coal in the pillars (or panels) can be extracted in one operation, the pillars are usually made large (from 50 × 100 yards to 100 × 200 yards), being usually longest on the strike side.

The length of the dip side is frequently determined by the means of coal getting.

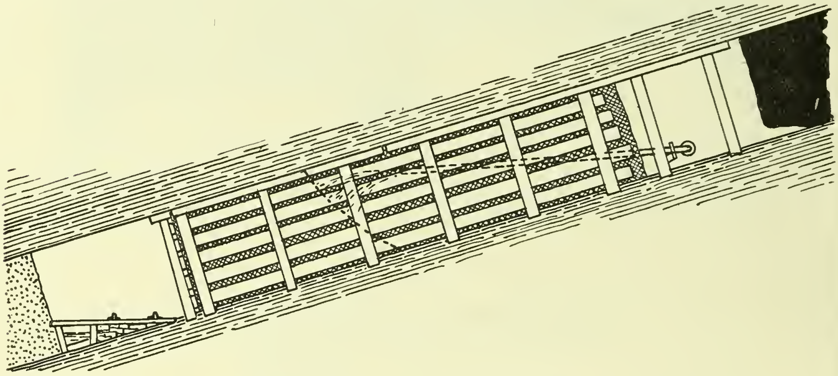


FIG. 15.—METHOD OF WORKING A 12-FEET SEAM AT TARNOWITZ.

Where coal cutters or conveyors are used the dip sides of the pillars are usually made of convenient lengths to suit the mechanical cutters or transporters.

Owing to the comparatively small amount of vertical subsidence it is rarely necessary to have to rip down the roof in seams over 6 feet in height, which reduces the cost of opening out the pillars.

Fig. 16 shows a method of working large panels at the Deutscher Kaiser Collieries in a seam about 9 feet thick, where the panels are subdivided in the second working to provide an outlet for the water draining from the packs on either side of the main haulage roads.

In seams between 4 and 6 feet thick the main haulage roads only are ripped, one to every 120 or 160 yards face.

The *debris* obtained from ripping is used to build *drainage-packs* on either side of the main road.

The general plan of this arrangement is similar to ordinary advancing longwall, except that the headings and levels have previously been driven to carry the pipe line for packing.

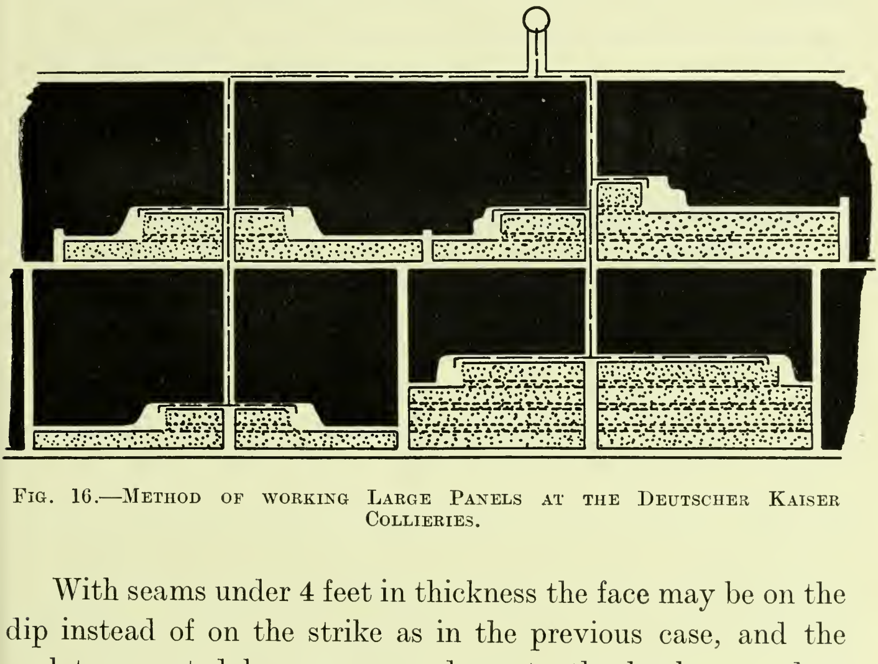


Fig. 16.—Method of working Large Panels at the Deutscher Kaiser Collieries.

With seams under 4 feet in thickness the face may be on the dip instead of on the strike as in the previous case, and the coal transported by conveyors down to the haulage road as shown in Fig. 17.

In the South Wales and Monmouthshire coal-field there are seams varying from 2 feet to 30 feet in thickness at inclinations varying from the horizontal to 35° dip.

In many districts there are huge unsightly rubbish tips which could be transported back to the mines.

In the Western area many of the collieries are within a reasonable distance of high deposits of sand, which forms the

cheapest packing material so far as the flushing process is concerned.

It is therefore surely possible to find some suitable colliery at which to make a trial of a system which has been successfully adopted in every other coal-producing country in the world.

Principal G. Knox traced the history of hydraulic stowing from the time it automatically applied itself 40 years ago in the case of the overflowing of the river Dee, which filled up some mine workings. After a considerable period, when the mine came to

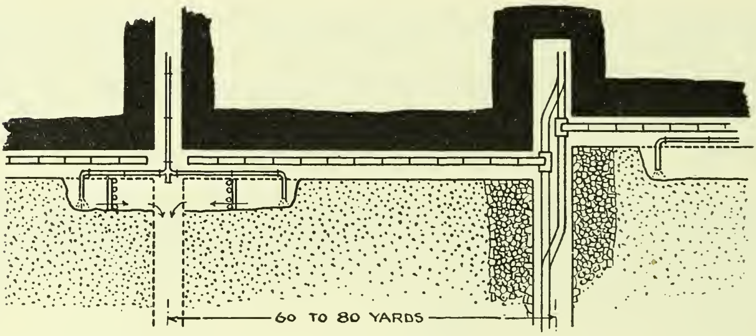


Fig. 17.—Seams under 4 feet thick with Face on the Dip instead of on the Strike.

be opened out it was found that the sand had completely closed the workings. The system was introduced from an engineering standpoint in America 37 years ago for the purpose of cutting off gob fires, and since then some parts of the Fife coal-field had been treated in the same way. Subsequently a German engineer who had seen experiments in France told some of his friends about it, and as a result a large hydraulic plant was installed by one of the large German colliery companies. From that time until 1914 when they were able to get about Germany and see what they were doing it was found that most remarkable developments had taken place. Members of the Institute who paid a visit to the Lake District last year had an opportunity of seeing the method of working in connection with iron ore

mining. There they were taking out a very thick deposit of iron ore, which seemed to him would lend itself to this system of stowing. As some of the members knew, the amount of money which had been spent in that particular district owing to subsidence was very considerable. They spent very large sums in putting up sea-walls and then taking out the iron ore from underneath the area enclosed. It just showed how insular they could be in things of this sort. In many districts in this country, particularly in the Midlands—Staffordshire and Derbyshire—they had conditions which were admirably suitable for hydraulic stowing, but no one had thought it worth trying. He had taken a party of engineers from this country to see the methods of working and the installations on the Continent, which they thought remarkable and should be adopted here. They had seen Krupps' system working at Essen in a mine close to one of their large iron and steel works. It was explained that previous to the adoption of hydraulic packing the pits in the district were about to close down. Owing to valuable property on the surface, they were restricted from working more than a certain percentage of the coal; practically it amounted, roughly speaking, to 50 per cent. of coal being left in. Krupps applied to the Government with a view to applying this system on the condition they were allowed to take out the extra coal. They were first allowed to work at one of the pits adjoining their large ordnance works, and when it was demonstrated that no damage resulted from the workings, although they took out practically all the coal, the Government gave them permission to take out all the coal in the whole area. They visited Liége, where they were shown a place where the old system of hand packing finished and where hydraulic stowing was commenced. The line was quite distinct all along. The members of the party were quite enthusiastic about the system, but

when they returned to this country they forgot all about it. They saw that this system could be applied successfully in those countries for all classes of working—then it surely could be applied in this country. Our mines were not so much different from those in other parts of the world. Many objections were raised against the system, but they had in the past got rid of bigger difficulties. He thought it was about time an effort was made to give the system a trial. They had parts of the coal-field where there was a long stretch of sand quite close to the collieries. If the system was tried they could put down a very cheap installation.

The Discussion.

Mr. G. D. Budge.

Mr. G. D. Budge thought that before they could make any remarks they should see something of the lay out of the workings. It was a very interesting paper and Professor Knox had more or less thrown out a challenge that they were out of date. Hydraulic stowing was a matter of interest to them in South Wales, where most of them were taking out large quantities to the surface. He would, however, reserve any further comments he might like to make until a later date.

The President.

The President said he would prefer reading and studying the paper before taking part in the discussion. He had had some experience of hydraulic stowing, not in a coal mine, but in an iron ore mine. He had always been enthusiastic about the system provided they got the circumstances that would suit it, but he had not yet been persuaded that the system could be applied anywhere. It was a question of economics. He believed that at the iron mine he referred to operations were started in 1906, but it was only on a small scale. It was adopted to extract pillars of iron ore, some of them 60 feet, standing in a steep gradient under houses and streets, which necessitated so much filling up before they took out a ton of ore. It entailed much capital outlay before they saw any return at all. The problem they now had to face was a rather different one to ordinary hydraulic stowing in a quarry, and when they came to apply the system to South Wales it seemed to him to be a totally different operation. They had to consider what were the conditions they would get for applying this system. First of all there was the question of subsidence. They had districts in the coal-field where there were narrow valleys very closely built upon and they had mountain-sides which were liable to slide, as some of them knew. But a large

The President. part of the takings were under mountain land which so far as subsidence was concerned was not worth spending money to support. So that from the subsidence point of view the amount of hydraulic stowing that would be necessary would be for a comparatively small area. They would not want to apply it to the whole of a colliery if it meant increased cost. Another advantage claimed for the system was that more coal could be extracted. That would apply where they had very thin seams. In this coal-field they took out pretty well all the coal in front of them, and the adoption of hydraulic stowing would only have the effect of enabling them to send out a little more of the small coal now left underground. From his knowledge and experience, however, the small coal which was now left underground was of a very dirty nature, and nearly all the rateable small coal was now brought out at most of the good collieries. That being the case, he did not think they could get any great advantage in that respect. They might gain something in reducing the cost of maintenance of roads. If it was possible to apply hydraulic stowing at a cost which would save them on timber as much as the extra cost of the stowing, there might be something to be said for hydraulic stowing in this district. But they were always faced, except in certain parts, with the difficulty of getting suitable material. There were big pit-heaps, but these were very mixed and contained a lot of clay. From his own experience of stowing with sand, directly it began to contain clay the difficulties were very largely increased. The question first of all was whether they would be able to get sufficient suitable material, and then there was the question of cost—whether they could stow with the material and save sufficient on the cost of rippings and timber, etc., to compensate for the extra expense. If they had to carry the material any distance it would cost more than the present system. At the iron mine in Cumberland, where sand

had to be brought a considerable distance by rail, the great difficulty was that they could never rely upon deliveries. They were often kept with nothing to do because of inadequate stocks, and as a result they were unable to carry on as economically as they would like. In Germany they had laid themselves out to get lower railway rates for stowing material. In this country, however, the present railway rates made it almost prohibitive to carry material into the coal-field. Unless the material was on the spot they would have to persuade the railway companies that it was worth their while to give special rates for such material. **The President.**

Discussion on the paper was adjourned, and the proceedings terminated.

THE FROTH FLOTATION OF COAL.

By Frank Butler Jones.

THE FROTH FLOTATION OF COAL.

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In the following paper an attempt is made, not only to describe what coal flotation is, and how it is put into practice, but also to indicate some of the peculiar advantages to be obtained by its use for treating materials of certain important classes, and to consider the nature of some of the benefits accruing from these advantages.

The attainment of these objects with any degree of completeness renders unavoidable the inclusion of a certain amount of material already quite familiar to the Members of the South Wales Institute of Engineers ; and it is hoped that this will be recognised as a necessary evil, and due allowance made.

General Applications.

The froth flotation of coal may be put into commercial application for two distinct purposes, viz. :

(1) The cleaning of raw coal.

(2) The recovery of clean coal from waste, including :

(*a*) Pit, belt, and washery waste.

(*b*) Washery silt (semi-waste).

Although the actual mode of separation by flotation of the coal from its impurities is the same in the two cases, the economic considerations governing the installation of the

process are widely different. The very high efficiency of the method makes it eminently suitable for the cleaning of raw coal, owing to the completeness of the resultant separation of the coal from the impurities, and it is mainly for the sake of this high efficiency and its attendant advantages that flotation is to be recommended for the cleaning of such material. A cleaned product containing about 99 per cent. of the free coal present and substantially free from impurities may be confidently anticipated in most cases. On the other hand, with respect to its usefulness in recovering clean coal from waste, the method of flotation stands alone, for, as far as is known to the author, no other process is capable of doing this profitably on a commercial scale. The treatment of waste is carried out for the sake of the value of the coal recovered, and although implicitly realised, the efficiency of the process becomes a factor of secondary importance. For example, the extraction of only 90 or 95 per cent. of the coal contained in a heap of waste might still yield a good margin of profit, and therefore form a sound commercial proposition. On the other hand, in the cleaning of raw coal a high extraction of the values is essential, and any considerable loss of coal would be a serious handicap.

The Cleaning of Raw Coal.

In many coal-producing localities in this country the best seams are approaching exhaustion, and as inferior seams are opened up, both the size and the grade of the coal become poorer. A larger proportion of small and dirty coal is produced, and the impossibility of cleaning material of this class adequately by the methods used on larger coal becomes more and more apparent.

The degree to which any given size of coal can be cleaned by any process depends upon three main factors, viz. :

(1) The proportion of fixed or inherent ash in the true coal.
(2) The extent to which the true coal is interstratified or intergrown with shale or other impurity.
(3) The amount of difference, with respect to some physical property, between the true coal and the impurities.

With regard to (1) it is evident that the fixed ash represents the theoretical limit to which the coal can be cleaned by any mechanical means, however finely it may be crushed.

The second factor (2) may be given a convenient numerical value by stating the maximum size or mesh to which the material would have to be crushed in order that the particles of true coal may be free from adhering particles of impurity. The effect of finely banded impurity on the cleaning of coal is obvious. Fortunately, in Great Britain, it has not *so far* been necessary to work seams wholly of this character; but in some countries such intergrown coal is among the best obtainable, and may in extreme cases necessitate crushing to pass $\frac{1}{20}$ in. or even $\frac{1}{40}$ in. aperture, before effective cleaning can take place.

Examples.

A. A sample of coal waste containing intergrown material was treated by flotation, after crushing to pass through $\frac{1}{10}$ in. and $\frac{1}{40}$ in. square apertures.

	Through $\frac{1}{10}$ in. mesh.		Through $\frac{1}{40}$ in. mesh.	
	Per cent. Wt. separated.	Ash per cent.	Per cent. Wt. separated.	Ash per cent.
1st product .	16·4	16·9	19·3	16·6
2nd ,, . .	6·3	46·1	11·2	43·2
3rd ,, .	6·9	61·8	5·0	63·4
Residue . .	70·4	78·8	64·5	86·1

B. Similar material from a different source.

	At $\frac{1}{10}$ in.		At $\frac{1}{40}$ in.	
	Per cent. Wt. separated.	Ash per cent.	Per cent. Wt. separated.	Ash per cent.
1st product .	18·7	20·5	22·6	14·1
2nd ,, .	4·6	47·7	9·0	43·6
Residue . .	76·7	71·5	68·3	78·6

In considering the third factor (3) it will be convenient to mention briefly the methods at present in general use for cleaning coal in this country, although of course this subject is quite a familiar one.

In the purification of large coal and other sizes down to $2\frac{1}{2}$ in. ring, the physical property mainly relied upon is colour or appearance, the impurities being as a rule quite different from the true coal in this respect. To a much smaller extent the density may form a guide, as, for instance, when black shale may not be quickly distinguished from dull coal, until its weight in the hand puts aside all doubt.

Slack coal through $2\frac{1}{2}$ in. ring is hydraulically cleaned in jig-, trough-, or cone-washers, before or after screening into convenient sizes. These 'coal washers' depend for their action upon the differences in rate of sinking in water, or, for particles of roughly the same size and shape, upon the differences in weight in water between the coal and the impurities. In operation on the larger sizes contained in the slack (nuts, beans, etc.) 'gravity' washers are generally fairly effective; but on small unsized coal ($\frac{1}{2}$ in. or $\frac{3}{8}$ in. to 0), their efficiency is very low. This is due, not to any fault on the part of the makers or of the operators of the machine (although many washers are not handled to the best advantage), but to the fact

that the application of jigs, cones, and troughs to the separation of unclassified small coal from its impurities is only a makeshift.

In order, therefore, that the more finely divided portion of the coal may be effectively cleaned throughout its entire range of sizes, it is evidently desirable to use a method that is *independent of the difference in density between coal and impurity* and owes its efficiency to a more pronounced difference in physical character, *one that is capable of treating material in a very finely divided state*, and *one moreover capable of operating efficiently on unsized material*. The want of such a method is supplied by flotation, for the process universally fulfils all the above important conditions, and has but one limitation; the coal treated must not contain particles larger than a certain critical size, although the degree of subdivision is otherwise immaterial.

It is, of course, a *sine qua non* for 'gravity' separation that the difference between the coal and its impurities with respect to specific gravity shall be reasonably large. A factor that in certain cases operates against the effective performance of 'gravity' washers is the presence in some seams of impurities differing only slightly from the coal in specific gravity. Specifically light, highly carbonaceous shales, low grade cannels, and plates of shale and gypsum—the last named by virtue of their shape—may all interfere seriously with the 'gravity' washing operation.

In the light of the foregoing, a rational method for the treatment of raw coals may be devised. Five cases arise, viz.:

(1) Slack (through say $2\frac{1}{2}$ in. ring) to be cleaned in sizes for sale.

(2) Coking slack to be cleaned entirely for carbonisation.

(3) Non-coking slack to be cleaned entirely for use in a fine state, *e.g.*, for briquetting or other special purposes.

(4) Coal finely interstratified with impurities, which cannot therefore be eliminated without fine crushing.

(5) Coal associated with certain impurities that hinder separation by hydraulic classification.

(1) The production of clean sized coal such as nuts, beans, and peas would be carried out as hitherto in 'gravity' washers. The small coal below a certain size, *e.g.*, $\frac{1}{2}$ in., would be separated from the dry raw slack, suitably crushed, and cleaned by flotation. In this way each particular class would be submitted to entirely suitable treatment, and therefore the highest possible efficiency would be obtained.

It is interesting to note that, when applied in this manner, flotation may actually be of direct assistance to the 'gravity' washer; for with the exception of that produced by accidental breakage, all fine material would be kept out of the washer, with the result that the water in circulation would remain relatively clean.

As an alternative the following modification of the above scheme may be of value in many instances.

The 'gravity' washer does not make a perfectly clean cut between coal and shale on any size of material. There is always a certain amount of overlapping on one side or the other, though this may sometimes be small. Therefore such a machine, dealing with material of fair size, may be operated to yield a clean coal and discard a coal-containing residue, or to yield only a moderately clean coal, and discard a residue substantially free from coal. Some washery managers make the production of very clean coal their aim, others take particular care of recovery, at the expense of the grade of the coal, while finally there are those who prefer to strike the happy medium.

Under the following scheme those who wish to make the cleanest possible material in all sizes may do so without fear

of loss, the recovery of the coal that would otherwise be lost in the discard being effectively secured by flotation.

After removal of the small coal for flotation, the larger coal would go to the jig washer, where a very clean coal and a coal containing residue would be made. The residue from the jig machine would be crushed to pass a suitable mesh and mixed with the crushed small coal, the whole going to the flotation machine for treatment.

(2) The cleaning of *coking slack* may be most conveniently and effectively carried out entirely by flotation, since the uniform crushing of the whole of the material is beneficial for the production of high-class coke. The advantage of using only one process and one plant is obvious. Among the first to realise the significance of flotation cleaning with respect to the production of metallurgical coke was a well-known firm of Cleveland ironmasters, and during the first half of 1920 careful tests were made at the iron works with the object of demonstrating the applicability of flotation to the cleaning of Durham coking coal. As a result, the company decided to adopt the process and in agreement with the Minerals Separation Company (proprietors of the flotation process) to instal a plant capable of dealing with the entire tonnage of raw coking slack, except, of course, that already sufficiently clean for direct coking.

(3) The case of *non-coking slack* (through say $2\frac{1}{2}$ in. ring) to be cleaned entirely for use in a finely crushed state is of infrequent occurrence, but when it arises flotation may be employed after crushing, as in case (2), with excellent results.

(4) In the case of finely interstratified or intergrown coal, clean nuts, beans, and peas cannot be made, since no effective cleaning can be attained above the critical mesh. In such cases flotation is peculiarly suitable, for it may be applied to material of any degree of fineness below about $\frac{1}{10}$ in.

(5) The case of coal associated with large quantities of impurities that do not differ greatly from it in specific gravity presents special features, and every such case must necessarily receive consideration from the point of view of commercial requirements.

For example, if clean nuts, beans, etc., are required, the application of flotation is limited to the smalls, and 'gravity' washers must be made to do the best work they can on the larger material. On the other hand, if the coal is required for carbonisation, briquetting, or other special purposes, or if it is finely interstratified with the impurities, flotation may conveniently be applied to the whole tonnage, as in cases (2), (3), and (4) above.

In this connection it may be stated here, although it is more fully considered below, that flotation accomplishes the separation of coal into grades or qualities, so that the presence of impurities not very different from the coal in density or buoyancy, but otherwise more strikingly different in physical nature, does not hinder effective cleaning by flotation.

The following examples illustrate the difference between flotation cleaning and jig washing when applied to fine coal.

C. Low grade coal from a Yorkshire field.

Method of treatment.	Cleaned coal.	Residue.
Jigging of $\frac{1}{2}$ in. to 0 size.	22·6 per cent. ash.	17·8 per cent coal recoverable by flotation (77 per cent. of this coal carried only 4·3 per cent. ash).
Flotation of $\frac{1}{2}$ in. to 0 size after crushing through $\frac{1}{10}$ in.	7·0 per cent. ash.	1·2 per cent. of bone coal. No high grade coal was present, the bone coal carrying 15·3 per cent. ash.

D. Low grade coking coal from the Durham field carrying 24·1 *per cent. ash.*

Method of treatment.	Cleaned Coal.	Residue.
Jig washing.	—	45·3 per cent. ash; 36 per cent. of coal with 8·3 per cent. ash recoverable by flotation.
Flotation after crushing through $\frac{1}{10}$ in.	Two products containing: (*a*) 5·0 per cent. ash, (*b*) 15·0 per cent. ash; average of *a* and *b*, 5·85 per cent. ash.	73·1 per cent. ash.

E. Coking fines carrying 23·2 *per cent. ash.*

Method of treatment.	Cleaned coal.	Residue.
Jig washing of — $\frac{5}{8}$ in. raw coal.	12·9 per cent. ash.	64·1 per cent. ash.
Flotation of jig-washed coal after crushing to $\frac{1}{10}$ in.	5·4 per cent. ash all products combined.	51·5 per cent. ash.
Flotation of — $\frac{5}{8}$ in. raw coal after crushing to $\frac{1}{10}$ in.	Two products: (*a*) 5·97 per cent. ash., (*b*) 20·10 per cent. ash; average of (*a*) and (*b*) 9·05 per cent. ash.	74·3 per cent. ash.
Flotation of jig residue after crushing to $\frac{1}{10}$ in.	Two products: (1) 12·3 per cent. ash, (2) 31·5 per cent. ash. Total (1) and (2) combined comprises 18·8 per cent. of the weight of jig waste and carries 22·1 per cent. ash.	72·8 per cent. ash.

F. A sample of jig-washed coking slack ($2\frac{1}{2}$ in. to 0) was *crushed to $\frac{1}{10}$ in. and further cleaned by flotation.*

The jig-washed coal carried 8·50 per cent. ash.

The flotation recleaned coal carried 4·77 per cent. ash.

The flotation residue carried 58·5 per cent. ash, and amounted to 7 per cent. by weight of the original jig-washed coal.

The Recovery of Coal from Waste.

Colliery waste from the pits, the picking belts, and the washery frequently contains a large proportion of coal, sometimes as much as 40 per cent. In the larger sizes, *free* coal should be, and in most cases is, conspicuous by its absence. Lumps of pit refuse and belt pickings often contain bands or adhering fragments of coal, which, of course, cannot be separated until the lumps are broken up.

The lump portion of washery waste does not as a rule contain much coal in the free state, but may carry a considerable proportion bound up with the shale. Among the many samples of washery waste examined by the author several have contained lumps of free coal even of nut size. This does not necessarily indicate careless working of the washer, for the particular owners may have considered the production of very clean coal of more importance than high extraction, and have caused the washer to be worked accordingly.

The finer portion of washery waste very frequently contains a considerable proportion of free high-grade coal. This is due to the fact that the average 'gravity' washer is, as already mentioned. incapable of dealing adequately with small material. Not only does washed small coal invariably contain quite a lot of free impurities, but also the corresponding small waste nearly always contains a valuable quantity of free coal.

When crushed below a suitable size, colliery waste of any kind may be deprived of the coal it contains by means of flotation.

Examples.

G. South Wales steam coal waste (taken from tip).

	Ash per cent.
Raw waste	47·7
Recovered coal (combined products) .	8·5
Residue	74·2

The coal recovered amounted to 37·5 per cent. of the raw waste, *i.e.*, 2·7 tons of raw waste yielded 1 ton of coal.

H. South Wales steam coal waste (Aberaman washery tip).

	Ash per cent.	Tons of waste required to yield one ton of coal.
Raw waste . . .	50·4	
Product 1 . . .	7·3	5·9
,, 2 . . .	13·0	
,, 3 . . .	22·9	
Residue . . .	75·2	
Products 1 & 2 combined	9·4	3·7
Products 1, 2 and 3 combined . . .	13·1	2·7

J. Durham coking coal washery waste.

	Ash per cent.	Tons of waste required to yield one ton of coal.
Raw waste . . .	45·30	
1st grade recovered coal	6·30	4·8
2nd ,, ,, ,,	11·05	
Residue . . .	68·65	
Products 1 and 2 combined	8·30	2·8

The Utilisation of Washery Silt.

The extremely fine coal that remains in suspension in, or forms a scum on, washery circuit water finds its way ultimately

to the silt ponds. In many collieries this material (silt) has up to the present been regarded as a dead loss; and while elsewhere it is dug out of the ponds when sufficiently dry and used for raising steam, a good economic outlet for the raw silt has not yet been found. It is invariably high in ash (about 30 per cent. is a common figure), and retains moisture most tenaciously, for, in addition to its shaley impurities, silt frequently contains clay, and this interferes greatly with free drainage, and even with drying by heat.

By means of flotation, clean coal can be recovered from silt, however finely divided the latter may be. The clean coal may be dried far more readily than the silt from which it was obtained, and may then be put to important uses, *e.g.*, as an ingredient of briquettes, or, when completely dried, for dust firing or colloidal fuel.

It will generally be conceded that although flotation thus provides means for the utilisation of existing stocks of silt, the best plan for the future would be to avoid making any silt. This also can be done by the aid of flotation.

Examples.

K. Washery silt from a Midland colliery.

Screen analysis showed:

	Weight per cent.
+ 20 mesh	2·0
− 20 mesh + 60 mesh	3·0
− 60 mesh + 100 mesh	5·0
− 100 mesh	90·0

Flotation yielded the following result:

	Ash per cent. (on dry basis).
Raw silt	30·5
Coal recovered (all products combined)	9·6
Residue	86·5

The coal recovered amounted to 71 per cent. of the raw silt, *i.e.*, 1·4 tons of raw silt (on dry basis) yielded 1 ton of coal.

L. Washery silt from a Scottish colliery.

	Ash per cent.	B.Th.U. per lb.
Original . . .	18·1	10,700
Cleaned coal . .	5·1	12,200
Residue . . .	68·9	2,500

1·2 tons of raw silt yielded 1 ton of clean coal.

The Principle of Froth Flotation.

It has already been remarked that a superficial property, namely, colour or appearance, has long been used for the separation of large coal from the accompanying shale and other impurities. Separation by flotation also depends upon a superficial property which, like colour, is only one manifestation of the chemical and physical nature of a substance.

When certain reagents are added in small quantities to water and the whole is agitated in the presence of air, very minute bubbles are formed. On allowing the liquid to come to rest, the bubbles do not coalesce but remain distinct from each other and rise to the surface, where a froth, often of an evanescent character, is formed.

If solid particles are suspended in the water, they may or may not, according to their superficial nature and according to the particular conditions imposed, become attached to the bubbles. On allowing the liquid to come to rest the bubbles rise to the surface and, if attachment of solid particles has taken place, a more or less stable froth is formed in which the solid particles are carried.

The constituents of ordinary uncleaned coal are such that under suitable conditions all may be floated by this means.

Coal flotation therefore involves, not merely the production of a solid-bearing froth, but also the differentiation by selective treatment of the various substances comprised in the mixture, whereby the worthless or deleterious impurities shall remain unfloated, and thus be separable from the valuable matter included in the froth. It is possible to do this, *i.e.*, to arrange the conditions, which may vary slightly in different cases, so that the coal is selectively picked up by the bubbles while the impurities are left behind ; these conditions once determined for any particular material, are easy to maintain on a practical scale. A further aspect of the process is that different kinds or grades of coal occurring together can be recovered separately and successively in a clean state, and it is desirable, in some cases, to take advantage of this grading, and isolate several products differing in ash content ; while in other cases where only one clean product is desired the different fractions may be mixed together. This application receives further notice below.

The advantage over hand picking is now apparent. The employment of a million human beings at a suitable picking belt would not suffice to separate coal from its impurities down to the finest sizes. The employment of myriad ants or other small insects would be more promising, but for the fact that they could not be trained to distinguish the various substances and separate them quickly and effectively. Air bubbles under the right conditions do not suffer from any such disability, but are able, when sent into a mixture of crude coal and water, specifically to select the coal fragments, which are thus, in the order determined by their nature, raised to the surface, whence they may be removed in bulk. Under proper conditions no particle, however small, is mistaken by the bubbles in their search for coal. The finest particles of shale are left alone, while those of coal are picked up unerringly and brought to the surface. On the other hand, a particle

of coal may be too large, and may escape inclusion in the froth solely because its weight is so great that the upward forces exerted by the bubbles are not strong enough to bear it. It is one of the conditions for success in separating coal from its impurities by flotation that no particle shall be greater than a certain size, determinable by experiment, and usually found to vary from $\frac{1}{8}$ in. to $\frac{1}{12}$ in. in linear dimensions. This is, of course, on the assumption that the coal is free from adhering impurities at this mesh; otherwise finer crushing must be employed.

Thus it is evident that separation by flotation does not depend in any way upon *differences* in density. The theoretical considerations underlying the principles of selective flotation are highly complex, and cannot be discussed here; it is apparent, however, from the results obtained, that under suitable conditions, coal of various kinds or grades on the one hand, and shale, grit, gypsum, etc., on the other hand, may be very strongly differentiated. The case of iron pyrite is exceptional; under the conditions most suitable for the separation of the other impurities this objectionable substance has floating properties. Owing, however, to its high density relative to that of coal, pyrite requires crushing to a much finer mesh in order that it may float. Being one of the hardest constituents of raw coal, it will under normal conditions of crushing occur mainly in the form of relatively coarse particles, and will thus escape inclusion in the coal froths. It is fortunate, moreover, that the best conditions for coal flotation are not the most favourable for pyrite flotation, so that the tendency of the latter substance to float is still further diminished. No trouble is to be anticipated from iron pyrite unless it occurs naturally in a fine condition, or in the form of thin, friable laminæ, and even in such cases separation to a certain extent may usually be effected. It is unfortunate that iron pyrite, when present in

these forms, is very difficult of efficient removal by any known commercial method.

It is clear from its mode of action that the process depends entirely on *surface* characteristics, and that if, say, a piece of shale could be given a firm coaly skin or covering it would behave just like a piece of coal, and *vice versa.*

In practice the water, preferably before admixture with the coal, is brought into a condition favourable to the formation of numerous small bubbles by the addition of a suitable 'aerating' reagent, *e.g.*, cresol; and at the same time air is introduced. The proper quantity of coal is added together with any other reagents that may be necessary in order to modify the water, the surface of the coal, or that of the impurities, and after a further period of agitation and aeration the pulp is allowed to come to rest. The bubbles carrying the coal rise to the surface and form a more or less stable froth, which, after removal from the liquid surface, readily breaks down and deposits its solid burden. The impurities, lacking the means to rise, sink to the bottom of the containing vessel.

The quantity of each reagent necessary to bring about the desired effect varies slightly according to the nature of the coal, but usually amounts to not more than a fraction of a pound to every ton of raw material.

In connection with the experiments carried out at an iron works it was found that the gas scrubbing effluent from the naphthalene towers used in the Otto direct recovery coking process contains substances that act as 'aerating' agents, *i.e.*, they are able to take the place of other soluble agents used in coal flotation. Such an effluent may be added to the flotation circuit water, or in some cases may be used without dilution as the whole circuit liquor. The effluent known as spent ammonia liquor may be employed in a similar way. In addition to the economy in reagents there is a further

advantage to be gained, for most of the objectionable matter is removed from these effluents by the coal, and their offensive and poisonous properties are largely destroyed.

The Flotation Machine.

On a commercial scale the Minerals Separation ‘ Standard ’ Coal Machine is used (Fig. 1). In design, this machine satisfies the basic condition that a pulp of coal and water passing continuously through it is subjected to alternate periods of agitation and relative quiescence. It is constructed of seasoned timber, and consists essentially of a number of similar units each performing similar functions. Each unit consists of an ‘ agitation box ’ rectangular in shape and square in cross section, combined with a ‘ frothing box ’ of V shape, the two being built together so that, viewed from the operator's position, the front side of the agitation box forms part of the rear side of the frothing box (Fig. 2), the two compartments communicating by means of a rectangular slot cut through the common side.

A number of these units built compactly together side by side constitutes the essential woodwork of a Minerals Separation ‘ Standard ’ Machine.

Inside each agitation box, and centrally situated a short distance above the floor of the box, is a cruciform agitator or impeller, keyed to the lower end of a vertical spindle. A single line shaft, mounted rigidly in a strong framework above the agitation boxes, drives the whole complement of spindles by means of bevel gearing.

Communication between each unit and the one adjacent on one side (either right or left but never both) is established by means of a ‘ circulating ’ pipe. Each pipe leads from the lower end of a frothing box into the agitation box belonging

to the next unit, through a hole in the middle of the floor of the box, the upper end of the pipe therefore emerging

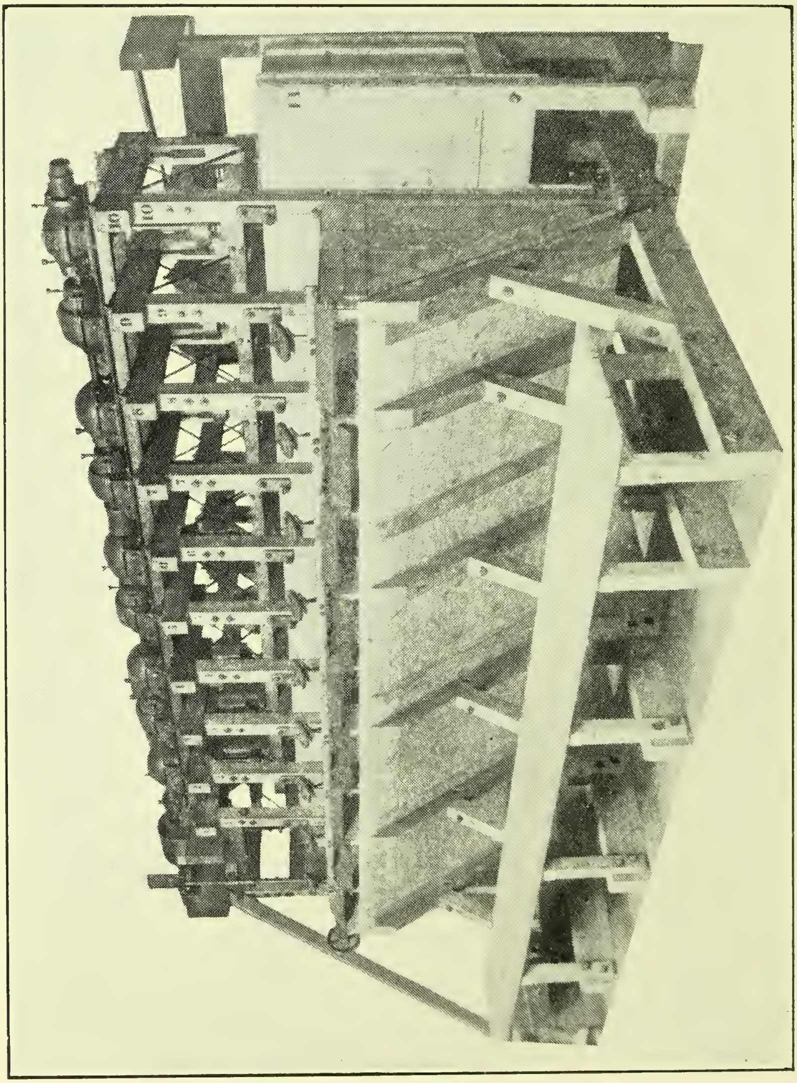


FIG. 1.—GENERAL VIEW OF A FROTH-FLOTATION PLANT FOR THE SEPARATION OF COAL.

directly under the centre of the impeller. The arrangement is shown diagrammatically in Fig. 2.

The frothing box end of each circulating pipe is throttled by a valve (the latter being controlled by a hand wheel),

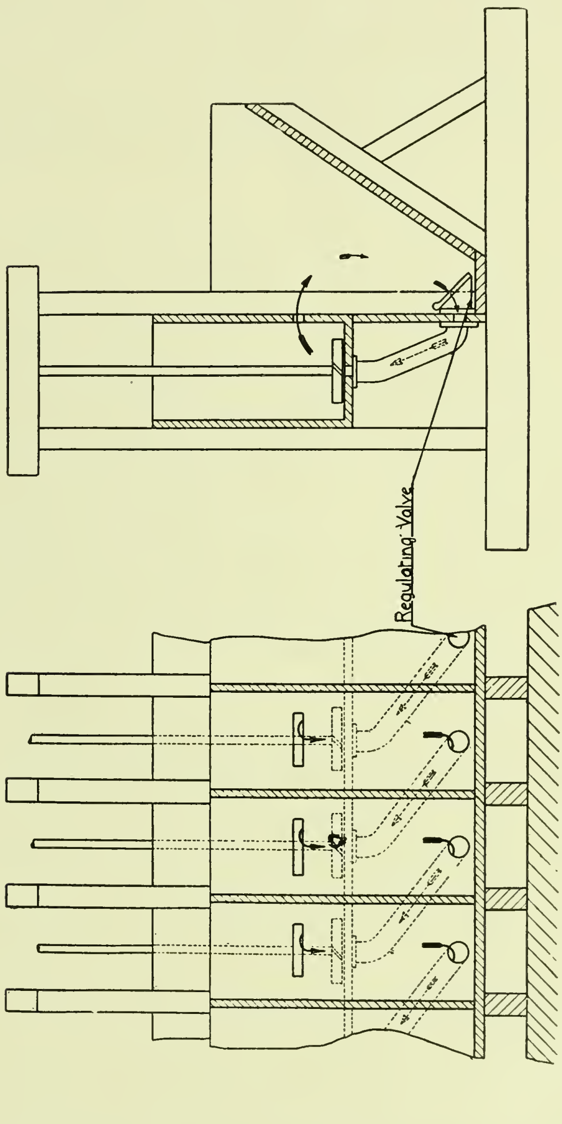


Fig. 2.—Showing Operating Details of Froth-Flotation Plant for the Separation of Coal.

whereby the rate of flow through the plant can be regulated, and great flexibility obtained.

The agitators function in three ways :

(1) They keep the contents of the agitation boxes in intimate admixture.

(2) They create a vortex in the pulp and thereby draw in the air necessary for flotation.

(3) They act as centrifugal pumps, keeping the contents of the machine in continuous translatory motion from feed to discharge.

The speed commonly employed is 1200 to 1300 feet per minute at the periphery of the impellers.

The number of units comprised in the plant depends upon the nature of the material undergoing treatment and is determined by small scale tests before the plant is constructed.

To start the process the machine is filled with water and the agitators are set in motion. This produces a general displacement of the water in the direction determined by the circulating pipes, and in order that a steady state may be maintained more water is continuously added to the first agitation box. Coal is added with the water in the proportion of one part of the former to four to six of the latter, and the necessary reagents are dropped continuously at a suitable rate into the same box. The pulp passes continuously out of agitation box No. 1, through the slot and away from the influence of the agitator into frothing box No. 1, and is there brought to a state of relative quiescence. The coal-laden bubbles rise to the surface and form a froth, and this is continuously removed by means of a revolving paddle, which carries it over the lip at the front of the frothing box. For various reasons only a portion of the coal floats in frothing box No. 1. That which fails to float remains together with the impurities in the pulp, which under the pumping action of No. 2 agitator is drawn through the first circulating pipe

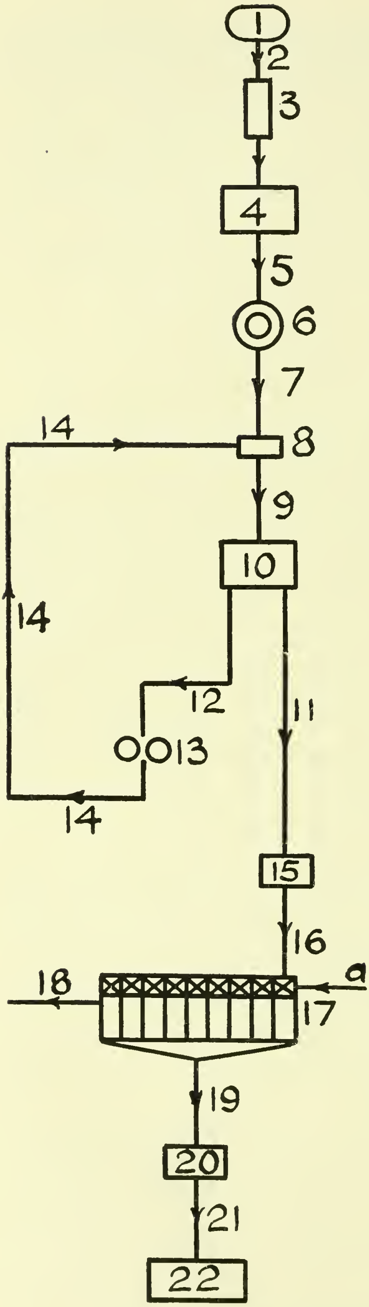
into No. 2 agitation box. On issuing into No. 2 frothing box more of the coal is floated, the remainder passing through the second circulating pipe into No. 3 agitation box; and so on through all the boxes to the discharge. In each agitation box the pulp is remixed and again aerated, so that in each frothing box it parts with some of the remaining coal, and arrives at the end of the machine free from that substance.

Operations on a Commercial Scale.

A description of the necessary equipment and its mode of operation may conveniently be given by reference to the small experimental plant installed at Aberaman under joint agreement between the Minerals Separation and Powell Duffryn Companies. The equipment of which the flow sheet is shown (Fig. 3) consists essentially of crushing plant (including a screen), flotation machine, and Oliver continuous vacuum filter, together with the requisite handling machinery. The installation is engaged in separating coal from a large dump of washery waste, and is capable of treating about six tons an hour.

As a result of the experience gained on this experimental plant, various modifications have been made, with the result that the present method of treatment shown in Fig. 4 is simpler than that originally proposed (Fig. 3). The amended flow sheet (Fig. 4) illustrates what will probably be the most common procedure for the treatment of colliery waste in this country.

The raw material enters the system at the boot of No. 1 elevator, and is discharged at the head on to the belt of a magnetic separator, which removes tramp iron. The remainder falls into a storage bin, from which it is removed by means of an apron feeder, and fed regularly into a coarse grinder of the



1. Tip.
2. Bucket elevator No. 1.
3. Magnetic pulley.
4. Storage bin for coarse crude.
5. Apron feeder.
6. ‘Coffee-mill’ grinder.
7. Chute.
8. Boot of elevator No. 2.
9. Elevator No. 2.
10. Vibrating screen (6 mesh, inclined at 45°).
11. Chute for undersize.
12. Chute for oversize.
13. Rolls.
14. Chute from rolls to boot No. 2.
15. Small storage bin for fine crude.
16. Screw conveyor.
17. 9 Box flotation plant.
18. Launder for residues.
19. Clean coal chute to filter.
20. Oliver drum filter.
21. Belt conveyor.
22. Truck.

a. Water line.

Fig. 3.—Original Flow Sheet of Flotation at Aberaman.

coffee-mill type. The discharge from this primary crusher passes to the boot of elevator No. 2, and at the head is delivered to the screen. The undersize passing through the screen gravitates down a chute into a small bin situated at the head of the flotation plant. The oversize from the screen surface falls to the rolls, is crushed between them, passes by gravity to the boot of elevator No. 2, and is re-elevated to the screen in admixture with fresh product from the primary crusher. The material is thus continually reduced in a closed circuit until it passes through the screen. By means of a screw conveyor the material contained in the small bin is fed evenly and continuously into No. 1 agitation box of the flotation machine, and a suitable quantity of water is delivered continuously into the same box. Reagents, consisting in this case of cresol and paraffin oil, are added in the first agitation box, and also may be added in any other agitation box at the discretion of the operator. The clean coal passes over the lips of the frothing boxes and falls into the tank of the Oliver vacuum filter. It is picked up by the filter drum, dewatered down to about 10 per cent., and discharged on to a belt conveyor and loaded into trucks. The waste material passes out of the machine and runs down a launder direct to the disposal site.

The procedure outlined above was found to require modification owing to the nature of the material undergoing treatment, for it was found that the small quantity of shale slime suspension paddled over with the froth impeded the action of the Oliver filter, although it was not present in sufficient quantity to have a marked effect on the grade of the clean coal. Since it had previously been shown that all the coal could be recovered in five out of the nine boxes of the plant, it was decided that the last four boxes should be used solely for re-treating the froth produced by the first five, the object

being to eliminate the shale slime and facilitate filtration. The desired result was fully obtained by this means at a trifling extra cost. No extra pumps were required, the impellers Nos. 1 and 5 doing all the pumping required. It is unlikely that re-treatment will be found necessary in dealing with raw coal, but it will probably be the general rule in cases where coal recovered from waste is dewatered by rotary filters.

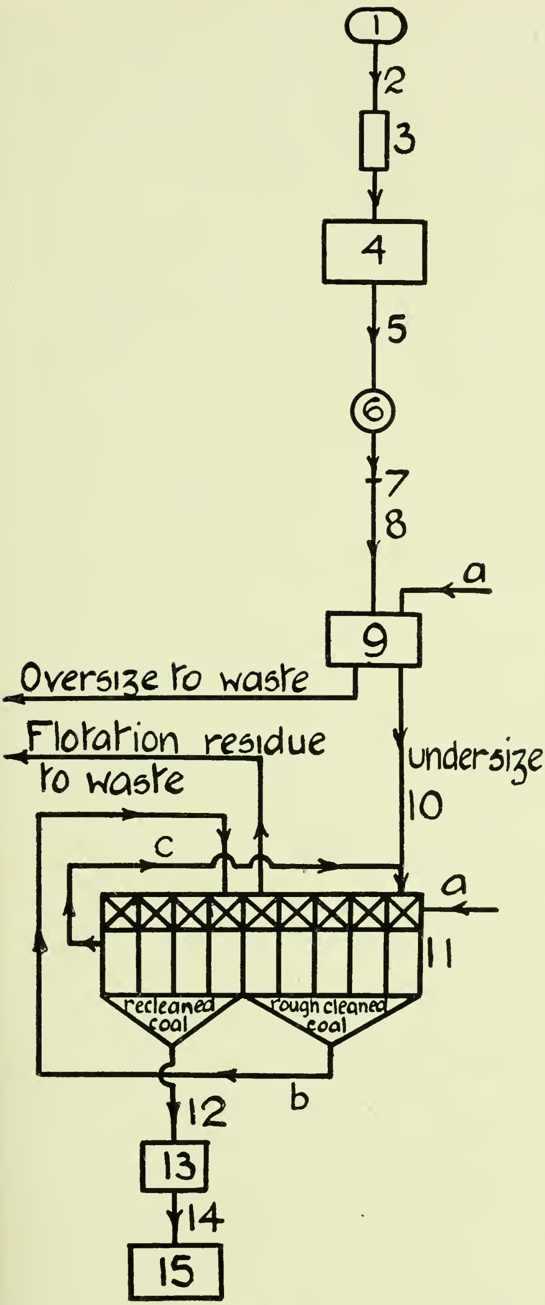
The modified flow sheet is shown in Fig. 4.

When the rainy weather came further alteration was found necessary. So long as the material was relatively dry the vibrating screen worked very well, but after rain had fallen on the dump for a few days it was found that the screen clogged very badly and needed frequent clearing, and it soon became evident that wet screening would be necessary. No facilities, however, existed for crushing the wet oversize, and on this account the mode of operation had to be modified considerably. A disintegrator was already in position, and this was set to work. It proved incapable of effecting the complete reduction of the raw material in one operation, but on the other hand it was found that the oversize from the screen contained very little coal and could be rejected without serious loss. Accordingly, it was arranged that the disintegrator should take the original feed and work in open circuit with the screen.

General Considerations.

The above being a description of the nature and mode of operations of a particular plant dealing with waste material, it is desirable to indicate some of the more general aspects of coal flotation practice.

Crushing.—The nature of the crushing plant required for any given proposition will vary according to the original size and according to the nature of the material intended for flotation.



1. Tip.
2. Bucket elevator No. 1.
3. Magnetic pulley.
4. Storage bin for coarse crude.
5. Apron feeder.
6. Disintegrator.
7. Chute.
8. Bucket elevator No. 2.
9. Wet screen.
10. Chute.
11. Flotation machine.
12. Clean coal chute to filter.
13. Oliver rotary continuous vacuum filter.
14. Belt conveyor.
15. Truck.

a. Water lines.

b. Rough cleaned coal pipe.

c. Pipe conveying retreatment residues.

FIG. 4.—MODIFIED FLOW SHEET AT ABERAMAN.

Owing to the fact that the determining conditions may vary widely, the consideration of methods of crushing becomes rather complex. For the sake of brevity it will be sufficient merely to indicate various cases that may arise, and offer suggestions as to a suitable mode of operation.

1. *Cleaning raw coal.*

(*a*) *Run of mine coal associated with hard impurities.*—A disintegrator of good type, working in closed circuit with a screen, may do the work, but it is probable that stage crushing will be necessary, for if the disintegrator should prove incapable of dealing with the shale, the latter will build up in the closed circuit, and ultimately choke the crushing plant. In such a case the disintegrator may be employed as a primary crusher in open circuit, the secondary crushing (of screen oversize) being effected by rolls working in closed circuit with the screen.

(*b*) *Small coal associated with hard impurities.*—The whole of the work in this case may be done by rolls of suitable dimensions working in closed circuit with the screen. The raw material would be fed direct to the screen, and the rolls would deal with oversize only. Stage crushing is unnecessary.

When material of intermediate size (say from 1 in. to 4 in.) is present, stage crushing is probably to be preferred. Large rolls are expensive, and it would be cheaper and just as effective to instal a disintegrator and small rolls.

(*c*) *Coal associated with soft impurities.*—Stage crushing unnecessary. A disintegrator in closed circuit with the screen would do all required. Original feed would go first to the disintegrator if mainly coarse, or first to the screen if mainly fine. Rolls might be preferred in some cases for the reduction of small oversize.

(*d*) *Coal too moist for dry screening.*—This case will probably

be of infrequent occurrence. In the case of coal associated with *soft* impurities no difficulty will be encountered, since wet screening in closed circuit with a disintegrator will give no trouble. When the coal is associated with *hard* impurities, however, wet screening and wet secondary crushing of oversize will be necessary. Small coal could be wet screened direct, the oversize passing to wet rolls in closed circuit with the screen. Larger coal would require disintegration before passing to the wet circuit.

2. *Recovery of coal from waste.*

(*a*) *Dry waste containing lumps.*—Stage crushing in 'coffee-mill' and rolls as originally at Aberaman would be suitable.

(*b*) *Dry small waste.*—Primary crusher is not needed.

(*c*) *Moist waste.*—Wet screening and wet crushing may be required.

(*d*) *Waste yielding very low grade oversize when reduced in a disintegrator.*—In this case the disintegrator and the screen work in open circuit, original feed going to the disintegrator. The oversize from the screen is rejected as too poor for treatment. Wet screening may be necessary (as at Aberaman).

3. *Any material already wholly below flotation size.*—No crushing plant is required, although a screen is desirable, in order that lumps of foreign material may be excluded from the flotation machine.

Screening.—The complete separation of the $\frac{1}{10}$ in. portion offers no practical difficulty if the material is fairly dry. The difficulties encountered when dealing with moist material have already received notice. In such a case, wet screening or classification are the only solutions.

The screens in which the necessary inter-movement of the particles is maintained by vibration of the screen wires give very good results.

Dewatering.—The Oliver rotary drum filter is the only machine that so far has been used for the dewatering of flotation coal. It does the work very well, and the indications are that at full capacity the cost will be relatively low.

In some cases filter bottom bunkers may be employed instead of vacuum filters.

A brief description of the Oliver continuous filter will not be out of place here. This machine, which is entirely automatic in operation, consists of a cylinder or drum mounted on a horizontal axial shaft. A suitable filtering medium of cloth or fine wire gauze is wrapped round the cylinder; the cloth is supported by a screen surface and is held in place and protected from damage by a spirally wound wire. The drum is actually a double cylinder, an annular space a few inches wide being the vacuum chamber. This annular space is divided into compartments by horizontal strips, each compartment being virtually independent of the remainder. The lower segment of the drum is immersed in a tank containing the material to be filtered. A special valve mounted on a trunnion at one end of the main shaft, and connected with the sections by means of pipes leading inside the drum, automatically controls the application of vacuum and positive pressure inside the sections. In operation the pulp is fed continuously into the tank, where it is kept in homogeneous admixture by means of a suitable agitating device. The valve is adjusted so that as the drum revolves each section in turn is put into communication with a vacuum pump during the greater part of a revolution—cake-forming and dewatering periods—and with positive pressure during a shorter part—cloth clearing period. A scraper bearing on the drum removes the dewatered cake.

During immersion the sections pick up the cake, and this is further dewatered by suction in air. As each section reaches the scraper, the cake is removed and the cloth cleared by a

'blow,' *i.e.*, change over to positive pressure inside the section. The scraper is a narrow sheet of metal fixed along the edge of the tank on the descending side, its bevelled edge bearing firmly upon the wire winding of the drum. The blow may be adjusted to take place either just before or just after the section reaches the scraper—preferably after in cases where minimum water in the cake is desired.

The water removed from the froth by means of the filter is perfectly clear, and may be used over again in the flotation machine. Since the water contains some of the reagents, its return to the circuit is desirable.

The water flowing away with the residue can only be used again when it is clarified by settlement, although perfect clarity is not essential. Here again a certain economy in reagents may be effected, although this is not the determining factor for water reclamation, which depends entirely upon local conditions.

Advantages of Flotation.

It has already been observed that, so far as the recovery of coal from waste is concerned, flotation stands alone, and in this respect it need not be further discussed. Some of the more important advantages of flotation when applied to coal cleaning may, however, usefully be indicated.

Efficiency.—The outstanding characteristic of the process is its extremely high efficiency. Separations may in many cases be made at the fixed or inherent ash value, implying the complete absence of free impurities. On the other hand, the residues contain no high grade coal and only occasionally small quantities of 'bone' coal high in fixed ash. In other words, the recovery of potential heat units is extremely high.

Treatment of fine material.—The facts (1) that no material

is too fine for treatment, and (2) that the separations are made on unsized material, place flotation in a class by itself. It is, of course, understood that flotation cannot be applied to lump material, and that it is approximately from the point where 'gravity' methods fail that flotation has scope.

Grading of products.—A salient feature of coal flotation is the fact that the various constituents commonly occurring together in coal are separated in the order of increasing ash content, this separation being to a large extent under control. Thus in the case of material consisting of free bright coal (clarain and vitrain), free dull coal (durain), a little intergrown coal, and free shale, the bright coal, containing the smallest quantity of ash, is separated first, followed by the dull coal, and then the intergrown coal. Since, however, small particles float more readily than large particles, a certain amount of overlapping is bound to take place, and for this reason the separation of one class of coal from another is seldom perfect; at the same time it is sufficiently pronounced to be of great practical use. The various products differing in ash content make their appearance in different frothing boxes, and may therefore easily be segregated.

The following tests carried out on Durham coking coal illustrate the manner in which bone coal of low coking value may be segregated from the high grade coking coal by taking advantage of the grading of products.

M.

Material.	Weight per cent.	Ash per cent.
Raw coal ($\frac{1}{10}$ in.) .	100	11·34
1st cleaned product .	82·7	4·30
2nd ,, ,, .	8·0	23·25
Residue . . .	9·3	65·35

N.

Material.	Weight per cent.	Ash per cent.
Raw coal	100	20·77
1st cleaned product .	69·4	5·00
2nd ,, ,, .	7·2	22·80
Residue . . .	23·4	57·00

The position of fusain (mother of coal, mineral charcoal) in this scheme is apparently anomalous, for, in spite of its relatively high ash content, the indications are that it invariably floats before any other constituent. This is possibly due to the fact that, being exceedingly friable, fusain occurs mainly in the most finely pulverulent portion of the coal, and thus secures an important advantage over the other constituents. The possibility of separating finely divided fusain by flotation is of great importance, since its presence to any marked extent in coking coal is considered to be deleterious.

Applications of Clean Fine Coal.

These fall naturally into three categories :

(*a*) Non-coking coal (including anthracite).

(*b*) Coking coal.

(*c*) Gas coal.

(*a*) *Non-coking coal.*—Among the uses to which clean non-coking fines may be put are the following :

1. Admixture with a somewhat larger size for the production of ‘ washed small coal.’
2. The manufacture of clean briquettes.
3. Dust firing.

4. Colloidal fuel.
5. As a metallurgical or chemical reagent, *e.g.*, in the smelting of zinc and tin and other metals, and in the Leblanc process for the manufacture of alkali. It is particularly important in every case of this kind that the coal should be as clean as possible; flotation implies great possibilities in this direction.
6. The manufacture of carbide, electrodes, etc., from 'super' clean anthracite.

Examples of cleaning of non-coking coal.

P. *Non-coking coal from South Yorkshire.*

	Ash per cent.	B.Th.U. per lb.
Raw coal . .	23·8	10,700
1st grade cleaned coal	4·0	13,400
2nd ,, ,, ,,	9·2	12,700
Residue . . .	82·8	1,400
1st and 2nd grades of cleaned coal combined . . .	5·2	13,200

Q. *Anthracite duff.*

	Ash per cent.
Raw material . . .	12·0
Cleaned products (combined)	3·7
Residue	73·8

(*b*) *Coking coal.*—At an iron works in Cleveland a short time ago a full oven charge of flotation cleaned Durham coking coal was carbonised and quenched under ordinary working conditions. The result was very striking, for the coke made contained less than 2 per cent. of breeze, against the 7 or 8 per cent. in usual practice on raw slack. This is an enormous saving. The examination of a sample of coke made at this works from flotation cleaned coal showed:

Moisture . .	0·60	per cent.
Ash . . .	5·35	,, ,,
Volatile matter .	0·50	,, ,,

The coke was strong, uniform, and dense, and of good cellular structure.

The advantages attendant upon the use of such coke in iron blast furnaces are very great. For the reduction of calcined Cleveland ironstone it is known from previous experience that about 22 cwts. of this coke may be expected to produce 1 ton of pig iron. The same class of raw coal when cleaned in a jig washer yields a coke of which 24 cwts. are required to produce 1 ton of pig iron, and when the coke is made from the raw coal 26 cwts. are consumed for the same object. The great reduction in ash content moreover implies a considerable saving of limestone flux. The coal from which this coke was made was the high grade flotation product from Durham coking coal, the lower grade coal carrying about 20 per cent. ash being excluded. In practice the low grade coal will be recovered separately and put to some useful purpose outside the coke ovens, *e.g.*, for raising steam.

During the early part of this year a quantity (about 10 tons) of coal from the Bristol field was separated by flotation into three products, viz. :

(1) High grade coal,
(2) Low grade coal,
(3) Waste,

and the high grade coal (1) was carbonised in a beehive oven. The coke obtained was of excellent quality and contained 6·1 per cent. of ash. The low grade coal (2) containing 15 to 20 per cent. of ash will in practice be burned under boilers.

The great advantages attending the use of high grade coke are well known, and call for no further comment.

The grading of coal that takes place during flotation cleaning may in some cases have very important applications. For example, in some coal and iron producing areas where the best coking coal locally procurable is of inferior quality, the metallurgical industries are obliged to depend upon distant markets for their supplies of coke. In some such cases it will doubtless prove feasible, by utilising the selective action of the flotation process, to effect such great improvement in the quality of the local coking coal, that the district will become largely independent of external supplies.

The following examples *R.* and *S.* show how high grade coal may be super-cleaned for special purposes.

R. Anthracite.

	Ash per cent.
Original	5·18
1st cleaned product . .	1·80
2nd ,, ,, . .	2·82
Middling	8·68
Residue	59·70

S. Coking coal.

	Ash per cent.
Original	2·15
1st cleaned product . .	0·75
2nd ,, ,, . .	5·60

(*c*) *Gas coal.*—The possibility of applying flotation to the cleaning of gas coal must not be overlooked. Although the carbonisation of gas coals under gas works conditions cannot, of course, result in the production of high grade coke, it is possible that, if the coal were thoroughly cleaned, *e.g.*, by flotation, before retorting, the coke would be so greatly improved in quality that the scope of its applications would be

considerably extended. There are numerous users of coke-fired crucible furnaces who would be glad to obtain, locally, small coke low in ash content, and would willingly pay more than the price of ordinary gas coke.

The Cost of Coal Flotation.

The essential cost of the actual flotation operations depends upon (1) the initial cost of the plant, and upon the cost of (2) power, (3) reagents, (4) labour, and (5) maintenance.

It is possible to indicate approximately the costs to be attached to the above items, for, calculated on a tonnage basis, they vary only according to exceptional local conditions, and are virtually independent of the original nature of the raw material. The cost of auxiliary operations, including handling, crushing (if necessary), and the dewatering and disposal of the products, must of course be taken into account in estimating the overall cost of erecting and running a particular installation. The cost of such operations cannot, however, be dealt with in a general way, for it is evident that conditions will vary considerably, so that each case needs individual assessment. In the same way the cost of water, including pumping, is a variable factor, and cannot be indicated in a general estimate. Four to six tons of water are required for the treatment of one ton of coal.

Items (1) to (5) above may now be briefly indicated, with regard to costs on a tonnage basis.

(1) The *initial cost* of a 40-ton-an-hour flotation machine, with driving motor and feeders for coal and reagents, is roughly £6000 erected and ready to run.

(2) *Power.*—A 40-ton-an-hour machine can be driven by a 40 horse-power motor. Therefore one ton of raw material requires 0·75 units (K.W. hours).

(3) *Reagents.*—In almost all cases the cost of reagents per ton of raw material treated is covered by the cost of $\frac{1}{2}$ to $1\frac{1}{2}$ lbs. of cresylic acid. Other reagents, in minute quantities only, may be required according to circumstances. When suitable waste liquors are available, the cost of reagents may be zero, or even negative, for the purification of poisonous effluents is certainly of value.

(4) *Labour.*—One semi-skilled man for each shift.

(5) *Maintenance* will cost very little. No data are yet available, for although coal flotation plants have been running for nearly a year, no repairs or replacements have so far been necessary. The cost under this head will, however, certainly be much lower than the corresponding charges for flotation plants treating metalliferous ores that contain quartz and other hard and abrasive substances. In such cases the whole cost of repairs and replacements, including all supplies except reagents, amounts in most cases to less than three halfpence a ton. It is probable that, for coal flotation, these costs will not exceed one halfpenny a ton treated.

The following is an approximate estimate of the total treatment costs for an installation at present under construction.

Raw coking coal through $1\frac{1}{2}$ to 2 in. ring, and containing about 30 per cent. of oversize $\frac{1}{10}$ in. is to be cleaned entirely by flotation at the rate of 40 tons an hour. Crushing of the oversize is to be carried out by rolls. The availability of a suitable gas-scrubbing effluent (from by-product ovens) eliminates most of the cost of reagents. The dewatering of the cleaned products to about 10 per cent. moisture will be effected by rotary continuous vacuum filters.

The cost of the site, buildings, and entire equipment erected and ready to run is about £30,000.

The power required includes :

	H.P.
For crushing and screening plant	24
For handling (inclusive of water, raw coal, and products)	22
For flotation	40
Total	86

Therefore the energy required to treat 40 tons of raw coal is 86 h.p. hours, or about 64 B.T.U. (K.W. hours); *i.e.*, one ton of raw coal requires 1·60 B.T.U.

The power required by the rotary continuous vacuum filters working on flotation cleaned coal is not at present accurately known, as the maximum capacity of these machines when dealing with material of this class has not yet been determined. The proved utility of these machines for dewatering finely ground metalliferous ore products indicates that they may be of great use for the similar treatment of fine clean coal.

In any case the cleaned product—which, as it leaves the flotation machine, contains about 50 per cent. of water and is practically free from clay and shale slime—drains quite readily in bunkers, especially in those with porous bottoms; so that no insuperable difficulty stands in the way of successful dewatering.

Labour (semi-skilled) may provisionally be put as follows:

Shift foreman
Crusher man
Flotation man
Filter man
Oiler
Helper

} for 320 tons of raw coal treated.

Residues.—These will gravitate to the disposal site in a water pulp. The cost of disposal will therefore be very low.

Water.—The use of gas scrubbing effluent reduces the cost of water to zero. The power required for handling water has been included above.

Maintenance, as already indicated, will cost very little, probably not more than 5 or 6 per cent. of the whole operating cost.

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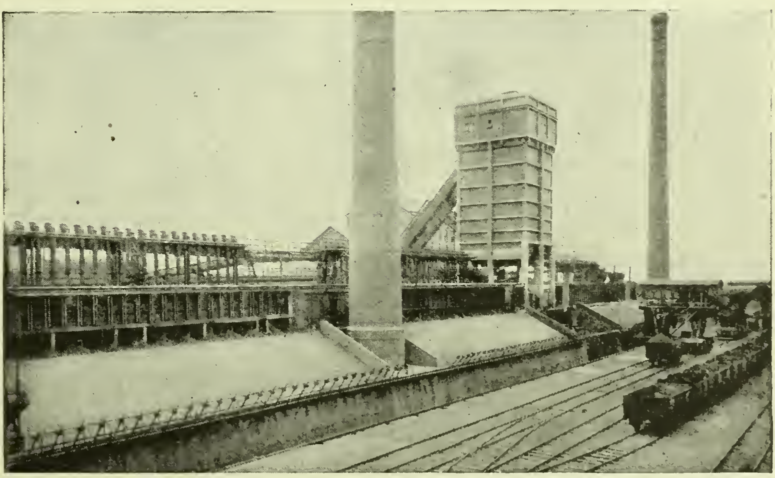

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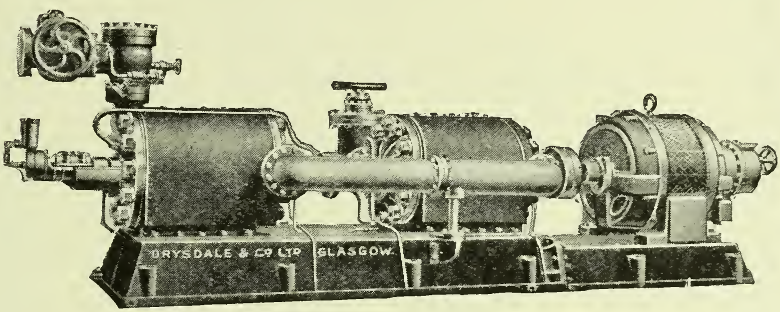

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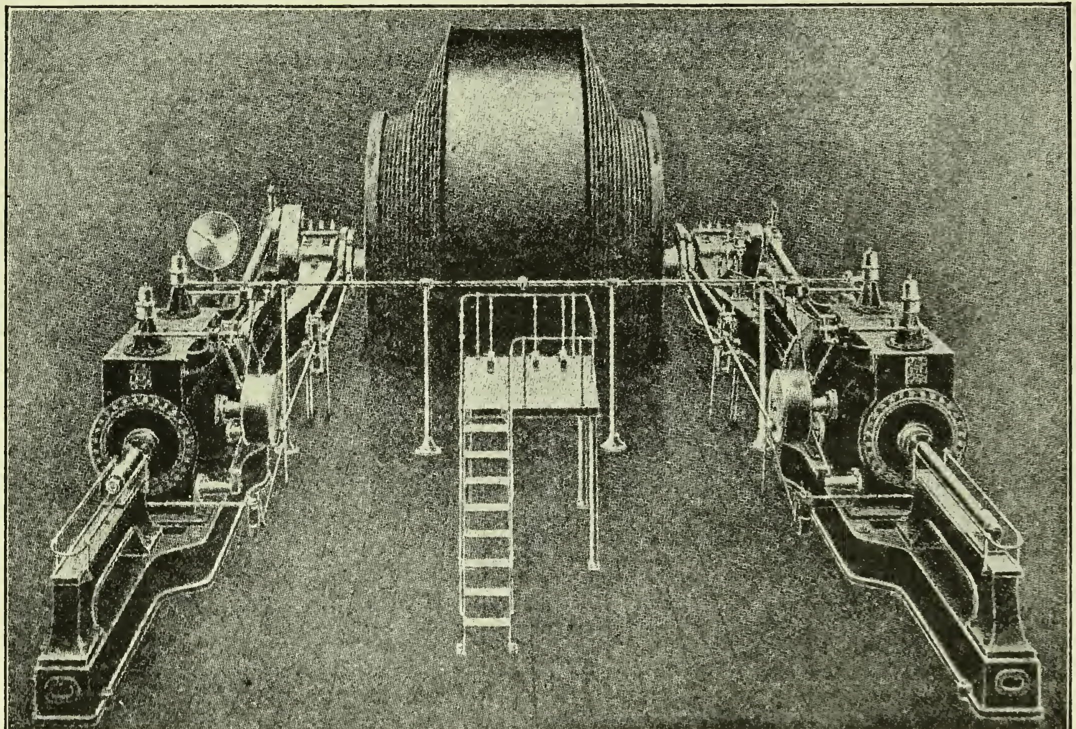

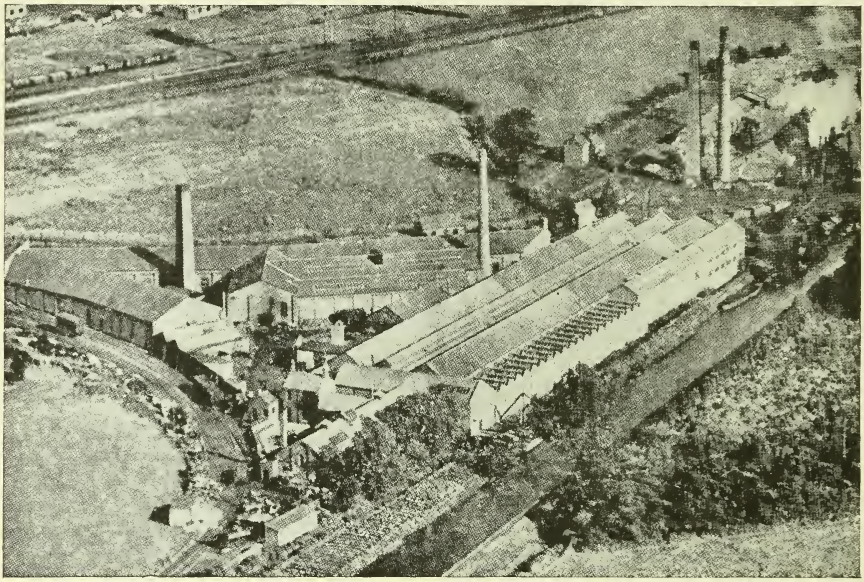

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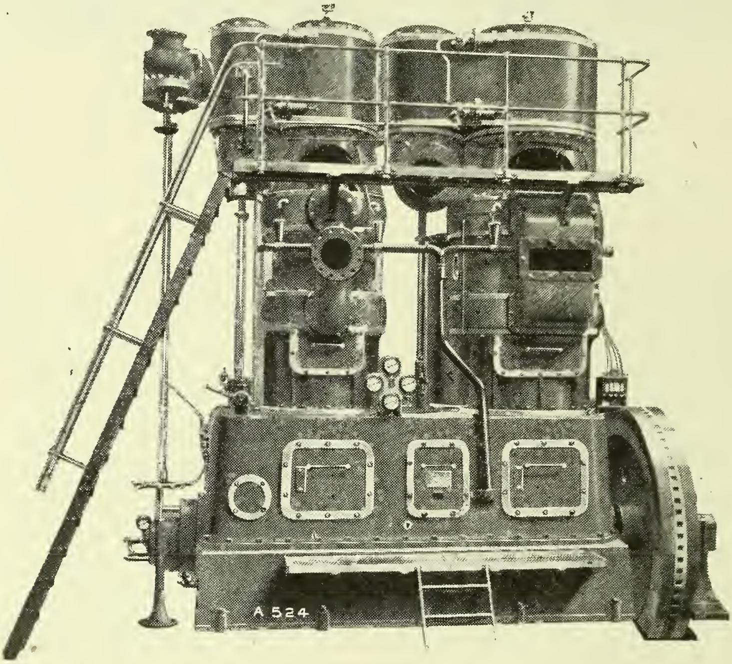

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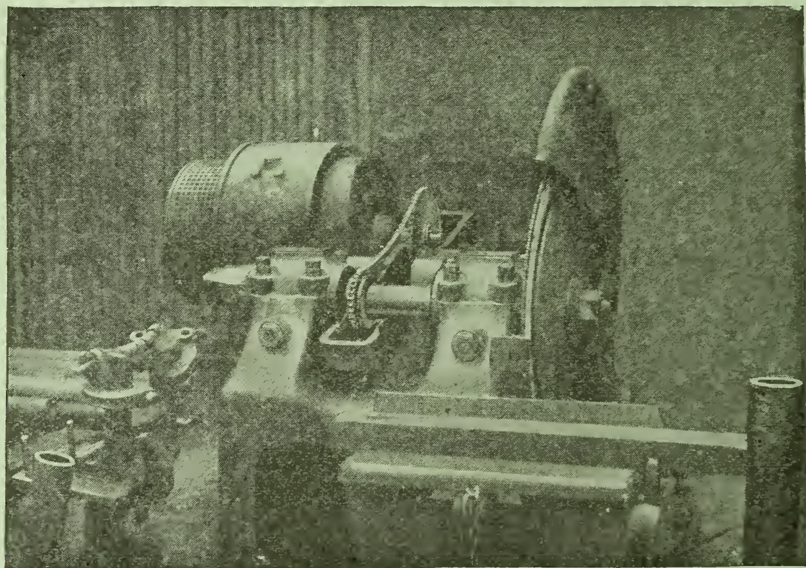

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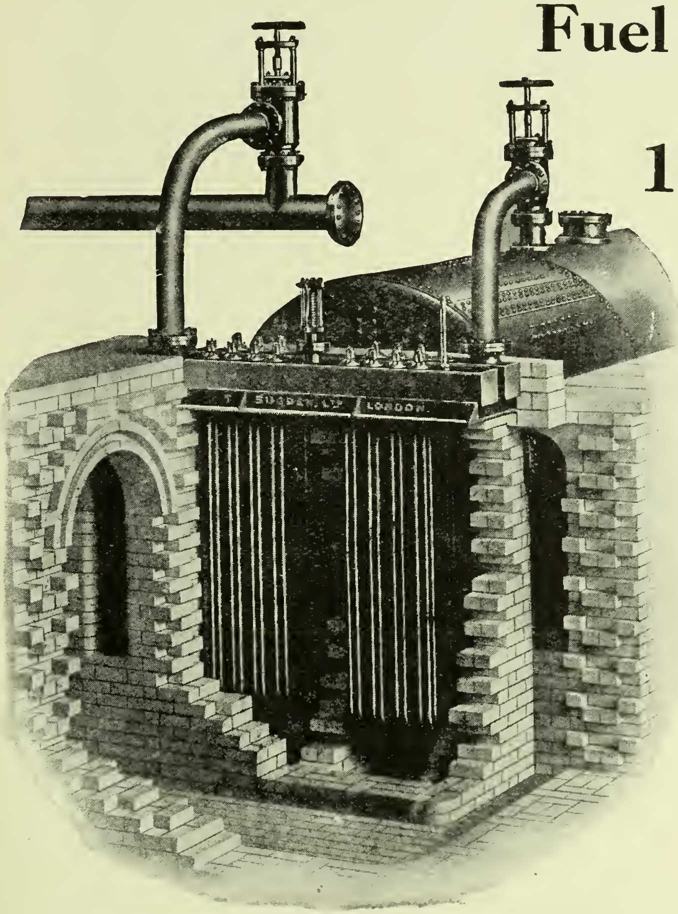

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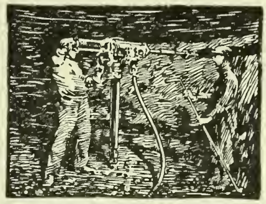

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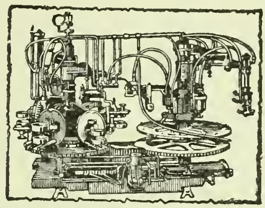

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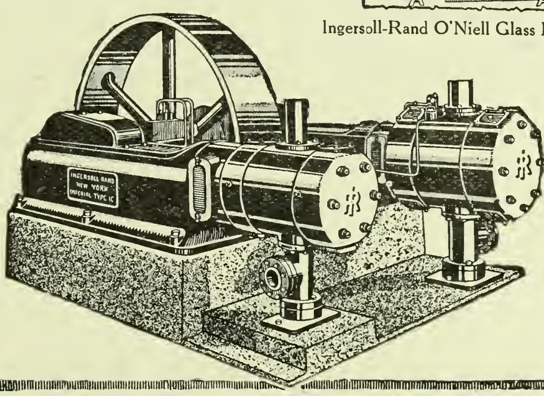

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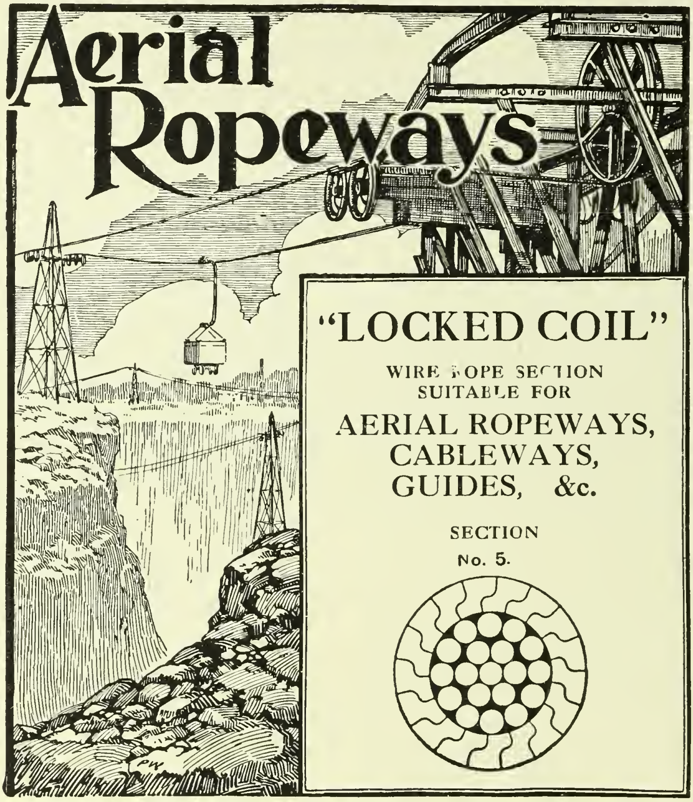

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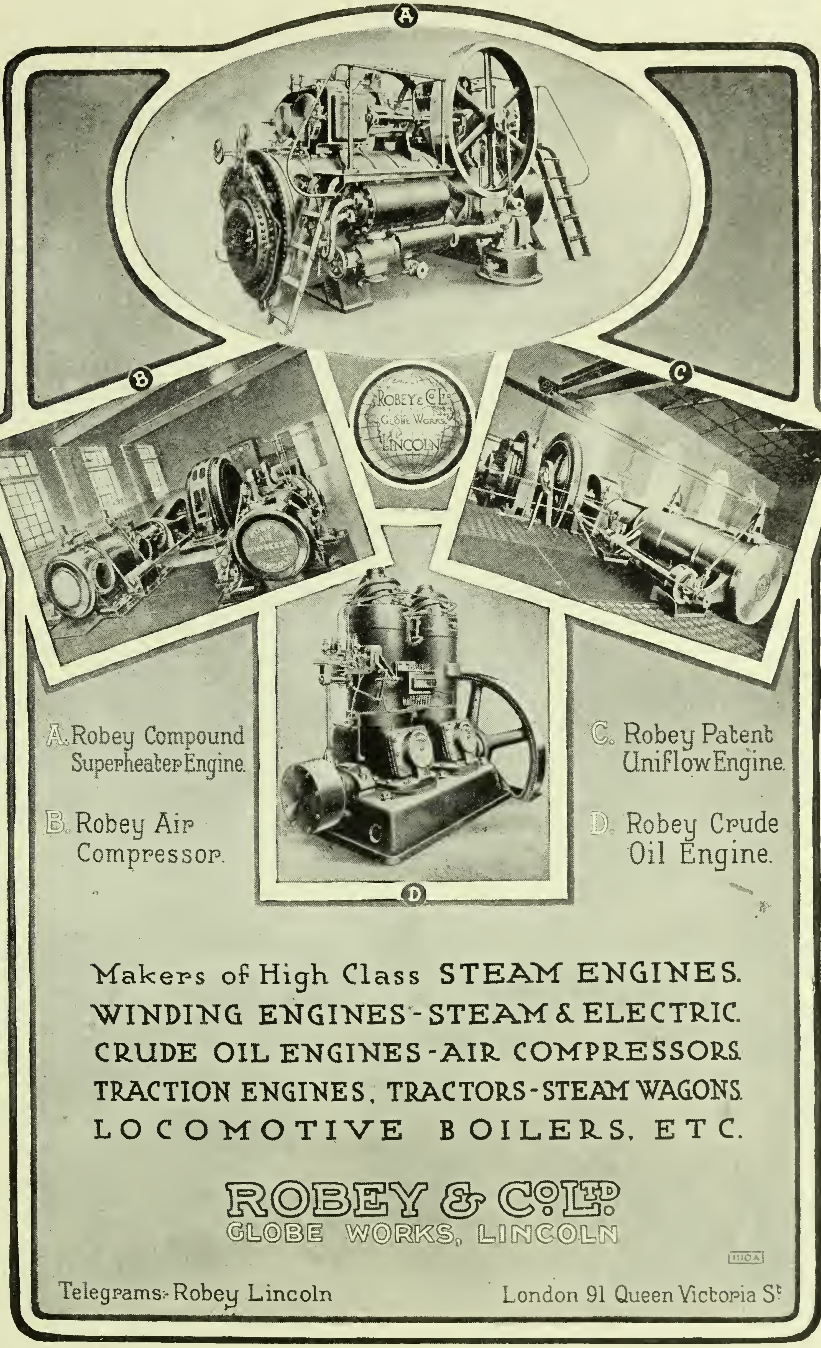
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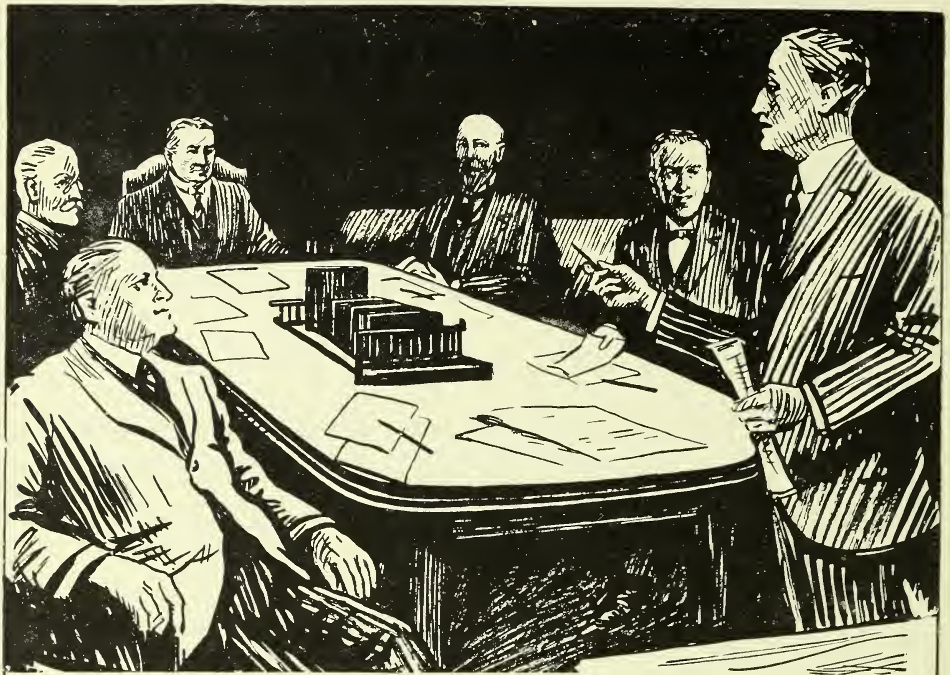

PAST PRESIDENTS

OF THE

SOUTH WALES INSTITUTE OF ENGINEERS.

1921.

	SESSIONS	
Menelaus, William, M.Inst.C.E. ...	1857–58; 1864–65...	(Deceased)
Rogers, Ebenezer	1858–59	(Deceased)
Clark, William Southern	1859–60	(Deceased)
Brough, Lionel	1860–61	(Deceased)
Adams, William, A.M.Inst.C.E. ...	1861–62	(Deceased)
Evans, Thomas	1862–63	(Deceased)
Basset, Alexander, M.Inst.C.E. ...	1863–64	(Deceased)
Martin, George	1865–66; 1866–67 ...	(Deceased)
Bedlington, Richard	1867–68; 1868–69 ...	(Deceased)
Lewis, Sir William Thomas, Bart., M.Inst.C.E. (afterwards Lord Merthyr of Senghenydd), G.C.V.O.	1869–70; 1870–71 & 1889–90; 1890–91	(Deceased)
Steel, T. Dyne, M.Inst.C.E. ...	1871–72; 1872–73 ...	(Deceased)
Brown, Thomas Forster, M.Inst.C.E.	1873–74; 1874–75 & 1891–92; 1892–93	(Deceased)
Brogden, James, F.G.S.	1875–76; 1876–77 ...	(Deceased)
Laybourne, Richard	1877–78; 1878–79 ...	(Deceased)
McMurtrie, James, F.G.S. ...	1879–80; 1880–81 ...	(Deceased)
Williams, Edward, M.Inst.C.E. ...	1881–82; 1882–83 ...	(Deceased)
Colquhoun, James	1883–84; 1884–85 ...	(Deceased)
Hood, Archibald	1885–86; 1886–87 ...	(Deceased)
Martin, Edward Pritchard, M.Inst. C.E.	1887–88; 1888–89 ...	(Deceased)
Stevens, Arthur J., M.I.Mech.E.	1893–94; 1894–95	
Martin, Henry William, M.Inst.C.E.	1895–96; 1896–97	
Jordan, Henry Keyes, D.Sc., F.G.S.	1897–98; 1898–99	
Evens, Thomas, M.Inst.C.E. ...	1899–00; 1900–01	
Riches, T. Hurry, M.Inst.C.E. ...	1901–02; 1902–03 ...	(Deceased)
Hann, Edmund Mills, M.Inst.C.E.	1903–04; 1904–05	
Deakin, Thos. Hedges, M.Inst.C.E.	1905–06; 1906–07	
Wight, William Dundas	1907–08; 1908–09 & July 1911 to Dec. 1911	
Rees, Ithel Treharne, M.Inst.C.E.	1909–10; 1910 to July 1911 ...	(Deceased)
Galloway, W., D.Sc., F.G.S., F.I.D.	1912	
Elliott, A. C., D.Sc., M.Inst.C.E.	1913	(Deceased)
Atkinson, Sir W. N., LL.D. ...	1913 (May 22 to Dec. 31, 1913)	
Wales, Henry T.	1914	
Griffiths, E. H., M.A., F.R.S. ...	1915	
Stewart, Wm.	1916	
Bramwell, Hugh, O.B.E.... ...	1917	
Tallis, John Fox	1918	
Dawson, Edward, M.I.Mech.E. ...	1919	
Lewis, J. Dyer	1920	

THE SOUTH WALES INSTITUTE OF ENGINEERS.

LIST OF OFFICE-BEARERS FOR SESSION 1921.

President.

BROWN, W. FORSTER, M.Inst.C.E.	Session 1921.

Past Presidents.

	Sessions
STEVENS, ARTHUR J., M.I.Mech.E.	1893–94, 1894–95.
MARTIN, HENRY W., M.Inst.C.E.	1895–96, 1896–97.
JORDAN, HENRY K., D.Sc., F.G.S....	1897–98, 1898–99.
EVENS, THOMAS, M.Inst.C.E.	1899–00, 1900–01.
HANN, E. M., M.Inst.C.E.	1903–04, 1904–05.
DEAKIN, T. H., M.Inst.C.E.	1905–06, 1906–07.
WIGHT, WM. D.	1907–08, 1908–09 & July to Dec. 1911.
GALLOWAY, W., D.Sc., F.G.S., F.I.D.	1912.
WALES, HENRY T.	1914.
STEWART, WM.	1916.
BRAMWELL, HUGH, O.B.E.	1917.
TALLIS, JOHN FOX	1918.
DAWSON, EDWARD, M.I.Mech.E....	1919.
LEWIS, J. DYER	1920.

Vice-Presidents.

ROBERTS, DAVID E., M.Inst.C.E.	Cardiff.
JOHNSON, WM.	Bridgend.
VACHELL, THEODORE, A.M.Inst.C.E.	Newport.
CHAMEN, W. A., M.I.E.E....	Cardiff.
HOOD, W. W.	Cardiff.
THOMAS, HUBERT SPENCE...	Whitchurch, Glam.

Members of Council.

KNOX, GEORGE, F.G.S., M.I.M.E.	Radyr.
DAVIES, J. C.	Gowerton.
HANNAH, DAVID	Penarth.
JOHNSON, T. ALLAN	Cardiff.
BACON, FREDERIC, M.A., M.I.E.E.	Cardiff.
SUGDEN, THOMAS, Wh.Sc., M.I.Mech.E.	London.
JONES, HOWELL R.	Dowlais.
GILBERTSON, FRANCIS W.	Pontardawe.
O'CONNOR, W., F.G.S.	Argoed, near Newport.
DAVISON, J. W.	Pontypridd.
LLEWELYN, Sir LEONARD W., K.B.E.	Newport, Mon.
THOMAS, TREVOR F., A.M.Inst.C.E.	Whitchurch, Glam.
NICHOLAS, BENJAMIN	Pontypool.
JACOB, F. LLEWELLIN	Ferndale.
HUTCHINSON, J. W.	Tondu.
SEYLER, C. A., B.Sc.	Swansea.
HANN, E. L.	Aberdare.
DAVIES, D. FARR, F.G.S....	Cross Hands, Llanelly.

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THE PRESIDENT'S GOLD MEDAL AND CERTIFICATE.

Established in 1904, and to be awarded—in the discretion of the Council—for the best Papers read in each Presidential term.

1904.

THE FIRST GOLD MEDAL

WAS AWARDED TO

Mr. HENRY K. JORDAN, F.G.S.

PAPER, "THE SOUTH TROUGH OF THE COAL FIELD, EAST GLAMORGAN.

1908.

THE GOLD MEDAL

WAS AWARDED TO

Mr. EDMUND MILLS HANN, M.Inst.C.E.

PAPER, "A RECENT PLANT FOR THE UTILISATION OF SMALL COAL."

1910.

THE GOLD MEDAL

WAS AWARDED TO

Mr. HUGH BRAMWELL.

PAPER "RE-SINKING AND RE-EQUIPPING THE GREAT WESTERN COLLIERY COMPANY'S MARITIME PIT."

1912.

THE GOLD MEDAL

WAS AWARDED TO

Mr. GEORGE G. HANN.

PAPER, "SINKING AND EQUIPPING THE PENALLTA COLLIERY."

THE INSTITUTE GOLD MEDAL.

In 1917 by Resolution of Council the name of the Medal, "The President's Gold Medal," was changed to that of "The Institute Gold Medal."

1917.

THE GOLD MEDAL

WAS AWARDED TO

Mr. GEORGE DOUGLAS BUDGE.

PAPER, "STONE DUSTING IN STEAM COAL COLLIERIES."

LEWIS PRIZE.

Founded in 1895 by the late LORD MERTHYR of SENGHENYDD (Past-President), K.C.V.O., M.Inst.C.E., for the best Papers on subjects connected with Practical Mining and Practical Engineering, including Metallurgy.

1898. A First Prize was awarded to Mr. E. H. Thomas for his Paper on "Haulage," and a Second Prize to Mr. G. E. J. McMurtrie for his Paper on "Sinking."

1900. A First Prize was awarded to Mr. S. A. Everett, and a Second Prize to Mr. E. H. Thomas, for Papers on "Colliery Surface Arrangements."

1901. A Second Prize was awarded to Mr. Ralph Hawtrey, a Student, for his Paper "The Best and Most Economical System of Working Seams of Coal of Moderate Inclination in South Wales."

1904. A First Prize was awarded to Mr. H. D. B. How, A.M.I.E.E., for his Paper "Coal Winding Machinery."

1905. A First Prize was awarded to Mr. W. Waplington for his Paper "Description and Design of the Best Arrangements of Equipment of the Bottom, with a Radius of 400 yards, of a Pair of Pits to be Upcast and Downcast Respectively."

1906. A Second Prize was awarded to Mr. George Roblings for his Paper "Separation (Sizing) and Washing of Coal."

1907. A First Prize was awarded to Mr. Daniel Davies, and a Second Prize to Mr. Gath J. Fisher, for their Papers on "Pumping and Drainage," and also on "Sinking Shafts."

1908. A First Prize was awarded to Mr. H. A. Staples, a Second Prize to Mr. George Roblings, and a Third Special Prize to Mr. M. D. Williams, for their Papers "As to the Best Methods of Working Seams of Coal in Steep Measures."

1909. A First Prize was awarded to Mr. William Trimmer, and a Second Prize to Mr. C. W. Jordan, A.M.I.Mech.E., for their Papers on "General Lay-out and Equipment of a Complete Set of Engineering Shops for a Modern Colliery with an Output of about 2,000 tons per day."

1910. A First Prize was awarded to Mr. George Roblings, and a Second Prize to Mr. Noah T. Williams, for their Papers on "Washing and Sorting of Small Coal."

1913. Special Prize awarded Mr. Will Gregson for his Paper "The Most Approved Methods of Hauling the Coal from the Working Faces to the Pit Bottom."

1914. Special Prizes awarded Messrs. J. Williams and S. R. Cound for their Papers on "How to Improve Welsh Tinplate Rolling-mill Practice."

1918. A First Prize was awarded to Mr. W. T. Lane, and a Second to Mr. W. H. Casmey, for their Papers on "Fuel Economy in Power Production (or Utilisation of Waste Heat)."

1920. A First Prize was awarded to Mr. R. C. Morgan for his Paper on "Causes of Subsidences and the best Safeguards for their Prevention."

1921. Subject selected: "Improved Mechanical Methods for bringing Coal from long distances in view of the necessity for Increased Output." 1st Prize £20, 2nd £10.

INSTITUTE SCHOLARSHIP IN ENGINEERING.

Granted by the Council in 1904, and tenable for three years at the University College of South Wales and Monmouthshire.

1904.—An EXHIBITION of £60, awarded to Mr. ERNEST CLARKE STROUD, Chatham.

1905-08.—A SCHOLARSHIP of £70 per annum, awarded to Mr. E. C. STROUD.

1908-11.—A SCHOLARSHIP of £70 per annum, awarded to Mr. IVOR RICHARD COX, Cardiff.

1912.—An EXHIBITION of £60, awarded to Mr. VICTOR JOHN FRENCH, Chatham.

1912-15.—A SCHOLARSHIP of £70 per annum, awarded to Mr. VICTOR JOHN FRENCH.

1915-18.—A SCHOLARSHIP of £70 per annum, awarded to Mr. E. W. H. KNIGHT, Devonport,

NOTE.—Mr. Knight was unable to take up the Scholarship he had won, and an honorarium of £10 was granted him by the Council, also a Certificate to the effect that he had won the Scholarship.

1919-12.—An EXHIBITION of £13 (plus a bonus of £15) per annum, awarded to Mr. E. G. DAVIES, Cardiff. (Won in 1915.)

1919-21.—A SCHOLARSHIP of £70 per annum, plus a bonus of £15 per annum, awarded to Mr. MYRDDIN DAVID, County School, Porth, and

1919-20.—An EXHIBITION of £30 per annum for two years, awarded to Mr. J. SELWYN CASWELL, EbbwVale.

NOTICES.

The EDITOR of these Proceedings is directed to make it known that the Authors alone are responsible for the facts and opinions contained in their respective Papers, and the individual speakers for their statements made in discussion.

He is also directed to state that the COPYRIGHT of all the Papers and Discussions published in these Proceedings is the exclusive property of the Institute, and reproduction of any of the Papers is prohibited unless in each case the consent of the Council has been previously obtained.

PROCEEDINGS.

Back Numbers of the Proceedings have now been bound, from Vol. I. inclusive, in Volumes, in strong Duro-Flexile Cloth, and may be obtained from the Secretary at £1. 1*s.* per volume, or separate back numbers can be had at the various prices marked on the covers.

CHANGE OF RESIDENCE.

The SECRETARY would be obliged by Members notifying to him any alteration in their addresses at the earliest date.

INSTITUTE BUILDING.

The INSTITUTE, Park Place, Cardiff, is open for the use of Members on Week-days from 10 A.M. to 5 P.M.

The NEW LIBRARY is now open for the use of Members, and the technical journals and other periodicals will be found on the tables in that room, instead of in the Council Chamber.

SPENCE THOMAS SCHOLARSHIP.

(Founded in 1918 by Mr. H. Spence Thomas for the encouragement of the Members of the Associations of Students of the Institute.)

The interest on £1,000 5 per cent. War Loan Stock shall be devoted to the Scholarship.

The Holder of the Scholarship must be a Member of one of the Students' Associations of the Institute, and must be a Student at one of the Colleges, Schools, or Institutions recognised as suitable by the Council of the Institute.

The Council of the Institute shall award the Scholarship upon Reports presented for its consideration by the Heads of any of the above Colleges, Schools, or Institutions, on the completion of one year's study by any student.

The College, School, or Institution shall present an annual Report to the Council on the work and progress of the Scholar to whom the Scholarship shall have been awarded, and the Council retains the right of withholding or cancelling the Scholarship, if in its opinion the progress of the Scholar is unsatisfactory.

In the award of the Scholarship the professional knowledge and practical experience of the candidate shall be taken into consideration.

No candidate will be elected to the Scholarship until he has satisfied the Council that his physical condition is satisfactory.

The Scholarship shall be awarded for a term of one, two, or more years in the discretion of the Council. The Scholar to briefly report at the end of each year upon the work accomplished.

The Council reserves the right to withhold the Scholarship if no candidate of sufficient merit presents himself.

1919–1921. The Spence Thomas Scholarship of £50 per annum was awarded to Mr. William John Gilbert, Nantyglo, for a period of three years, tenable at the School of Mines, Treforest.

INSTITUTE SCHOLARSHIP IN ENGINEERING.

Granted by the Council in 1921, and tenable for three years at the UNIVERSITY COLLEGE OF SWANSEA.

Session 1921-1922 to 1923-1924. A Scholarship of £70 per annum, awarded to Mr. John Brook Fortune, Swansea.

ADVERTISEMENTS.

For particulars of advertisement space in these publications, apply to The Business Statistics Company, Ltd., Baltic House, Cardiff, and 58 Victoria Street, S.W.

CONTENTS.

No. 5. Volume XXXVII., issued Nov. 10th, 1921, price 10s.

PROCEEDINGS.

An Ordinary General Meeting of the Institute was held in the Board Room of the Swansea District Board of the Monmouthshire and South Wales Coal Owners' Association, 62 Wind Street, Swansea, on Thursday, October 6, 1921.

The chair was taken by the President, Mr. W. Forster Brown, M.Inst.C.E.

The minutes of the preceding Ordinary General Meeting, held at Cardiff on July 14, 1921, were read and confirmed.

Election of Members.

The following candidates for admission to the Institute were declared to be duly elected :

As Members.

Leston, George Lionel . . .	Mountain Ash, Glam.
Owen, William John . . .	Bridgend, Glam.
Rosser, Samson	Ton Pentre, Glam.
Williams, Percy Edward . . .	Cardiff.
Yousef, Aly, M.I.M.E. . . .	Cairo, Egypt.

As Associates.

Elliott, Arthur	Talywain, Mon.
Williams, David John . . .	Nantyffyllon, near Bridgend, Glam.

As Student.

Rees, Frederick Lloyd . . . Abertridwr, near Cardiff.

Swansea College Scholarship.

The President. The President, before proceeding with the business of the Meeting, said it would be within the members' remembrance that the Institute had awarded a scholarship of £70 per annum for students at the University College of Swansea, and he was glad to say that the Council had that day been able to award this scholarship, on the recommendation of the Senate of the University College, to Mr. John Brook Fortune, Morley House, Mount Pleasant, Swansea.

Another announcement he would like to make was in connection with the two or three institutions of students which, as they were aware, were attached to the Institute. One had been formed in connection with Swansea College, and the inaugural meeting was to take place on November 4th, at 6 p.m., under the Presidency of Professor Bacon. He hoped that all the students connected with it would then attend.

Hydraulic Stowing.

By Professor George Knox, F.G.S., M.I.Min.E., and J. Drummond Paton, M.I.Min.E, A.M.I.E.E.

(For Paper, *vide* Proceedings, Vol. XXXVII., No. 4, p. 283.)

The President. The President said he believed Mr. Paton was proposing to show some further slides before they opened the discussion on this paper ; perhaps he would do so at this stage.

Mr. Paton.

Mr. PATON explained that he would not be able, as hoped, to show the latest developments of stowing which they knew, following some investigations of a system for long distances, so for the benefit of the Swansea section he would put through a few of the previous slides, describing the process from them as he proceeded. In incidental comment on the slides, Mr. Paton said he thought, from his observations while coming down to Swansea, there were very many dumps that would serve for stowing for a very long time, and some which must be costing a few shillings to tip. There was an economic consideration in relation to this material, both in regard to its removal from the mine, rendering sites available, and in regard to making things cleaner and better for the district. With these descriptions he would like the question discussed, and Professor Knox had better deal with its local aspects.

The Discussion.

Mr. H. T. Wales.

Mr. H. T. WALES said, after reading this very interesting paper, he asked himself the question, 'Is this method one that can be usefully applied in our own South Wales district?' and, in considering that, they should look at it from the points of view of, first, safety, and then economy and efficiency, and try to come to a conclusion. It seemed to him there were so many factors that would have to be taken into account that it would be almost impossible to arrive at any definite conclusion until they had seen the system itself in operation at some colliery in South Wales. He could quite understand there were cases in which this would be a most valuable system; for instance, where collieries are working coal under some of the cities of our own kingdom. Where several seams existed, and no system of this kind had yet been applied, it was necessary

Mr. H. T. Wales.

to leave a large proportion of the coal for support, so that where four, five, or six seams underlay a large city the amount of coal that would have to be left would mean a very serious loss. Again, he could quite understand from experiences he had had himself, that a system of this kind would be most valuable in any case in which a colliery was subject to spontaneous combustion to any serious extent. Had he known of the system and its application a few years ago he would certainly have considered its adoption in one or two cases in which, in its absence, spontaneous combustion had given rise to most serious expense and difficulty.

The President.

The PRESIDENT thought many present ought to have some idea as to the practicability of the system in the conditions with which they had to deal. They might give views on that point.

Mr. J. Dyer Lewis.

Mr. J. DYER LEWIS said he had read the paper with considerable interest and, as one who had a fairly good knowledge of mining conditions in South Wales as a whole, he hoped and trusted it would at any rate lead to the commencement of an experimental station in regard to hydraulic stowing. In several of their mines, where the headings and roadways were very extensive—in some cases a mile or two in length—it would probably entail considerable expense in the first instance; but where the seams were worked, as they often were, one above the other, especially in the lower steam coal series, he had a real belief that if it were possible to stow the upper seams thoroughly they would entail far less expense in the repair of the lower ones. He could mention cases in which, even with the methods of stowing at present used, where it had been done regularly and well the owners had far less expense in keeping the roadways in the lower seams open than in mines where no attempt had been made to stow properly.

As far as the south crop measures were concerned, there were several collieries which had a very large quantity of sand within easy reach. At one colliery he could mention, where they were working at the same time two or three seams in close proximity to one another, the expense of keeping roadways open must be very great indeed. In that same colliery they had had spontaneous combustion on one or two occasions, and he felt that if the property had been hydraulically stowed —there were thousands of tons of sand not very far away— it would be worked cheaper and a large quantity of coal could be obtained from it that was now lost to the country, while timbering, too, would be very much cheaper than at present. He would like the method tried in some of their seams, either in anthracite or in the south crop, because he thought in these it would have more chance of success in working the whole of the coal than probably in the steam coal measures. He was pleased that the paper had been given at this opportune time. **Mr. J. Dyer Lewis.**

Mr. D. F. Davies said he was sorry he had not read the paper as thoroughly as he would have liked. Still, he was very pleased it was available for the Institute, because it was one of the most emphatic papers they had ever had. It was a paper in which they saw ‘ success ’ from the very beginning. Mr. Dyer Lewis had suggested trying the system in the anthracite district, but unfortunately the anthracite seams were very thin, and there were very few which had not a thick clod coming down between the seam itself and the roof. As a rule, that clod was sufficient for efficient stowing, and there were few gobs left unfilled, except in the Big Vein, Gwendraith Valley district. That was the only seam in the anthracite district—in the steep measure part of it—in which he could see that this method of stowing would prove of great value, because that seam could only be worked by the pillar-and- **Mr. D. F. Davies.**

Mr. D. F. Davies.

stall method, and no doubt a considerable quantity of the coal left to-day could be efficiently and economically got by the use of hydraulic stowing. The great question to his mind was, 'Can it be done economically?' In the steep measure districts their trouble was now water, and the more they went to the deep, the more the water followed them. That constituted a sufficient trouble now, but hydraulic stowing would only add to it, because of the quantity of water introduced with every ton of rubbish, and it would also add considerably to the expense, because if the water from the stowing went to the bottom, they would have to pump against a very considerable head. So he thought re-pumping would be too costly to permit the adoption of the system in the anthracite district, even in the Big Vein workings. But if the contributors of the paper could show the cost of the method they would be much better able to say whether the scheme could be economically adopted in the Big Vein.

Mr. Dyer Lewis.

Mr. Dyer Lewis asked if the water mentioned by Mr. Davies need go to the bottom.

Mr. Davies.

Mr. Davies replied that he had tried leaving large pillars behind to prevent the water following them to the deep, but once a squeeze came on, either in the roof or the floor, and the pervious beds were broken into, down came the water again. He had met with very few leading headings to the deep that could be driven without a pump at the face, or a short distance back from the face.

Mr. G. Roblings.

Mr. G. Roblings said he also had read the paper with interest, and, as it happened, a note he had with him answered Mr. Dyer Lewis, although it was written days ago. He had places working where the water percolated through the floor for hundreds of yards, and they got all this water down into the main winning places. There was even now considerable difficulty in getting the men to work, simply owing to the

Mr. G. Roblings.

damp conditions, and the usual thing was, 'We shall want more allowance.' If they had the water from a stowage system added to the present they would have to stop developments, for developments were on the steep measures practically to the full dip continuously. In some of the seams in which machine mining was adopted possibly hydraulic stowing might be more economical than hand-stowing. As machine mining developed satisfactorily and efficiently, there was no doubt a considerable saving on ordinary working methods could be effected, but this was more than counteracted by the inability to pack the workings properly behind the machines. There were difficulties on the roads, as well as in the faces, when there was not this proper packing, particularly in steep workings. It would be interesting to know—and Mr. Davies had asked the question—as to the cost of the system of hydraulic stowing; but he feared that, however cheap it might be, they would hardly be able to make it pay on the comparatively small outputs which, owing to the difficulties arising out of the disturbances breaking the strata into so many divisions, they got from the anthracite collieries. He knew their friend Mr. Paton would in this connection 'throw up' the Hibernia seams. He had seen some of them, and the difficulties there were, he agreed, enormous; but there they did not develop so much to the dip as here, or follow the seam as they did in Wales, and there was not this trouble of the water following to the main winning places. It would be necessary to take practically the whole of the coal away in order to give a free gob, or else there would be little space left behind for stowing, and if their friends had not experienced the difficulty they had in South Wales with 'through' coals, he need only remind them of the great difficulty there had been in the last few years with those who had bought coal that was dirty owing to it being 'through'—

Mr. G. Roblings.

because through coal meant a very large percentage of rubbish. He did not think the workmen would leave any of this behind if the hydraulic system were adopted. However, there were undoubtedly many places with very long faces and comparatively thick seams where the water could be easily dealt with and where this system would be an excellent one.

The President.

The PRESIDENT said, before asking Professor Knox and Mr. Paton to reply, there were one or two aspects to which he would like to refer. It would add very much to the value of a paper already very valuable if the authors could give some further information upon one or two points that he regarded as rather practical. At the commencement of the paper reference was made to the forces brought into operation when an excavation had been made. Could they give any idea of what proportion of the gravitational forces brought into play (or, what proportion of the weight of the strata from the surface down to the excavation) would actually operate on the packs? And could they give any actual information as to the amount of subsidence of the packs when using sand, crushed slag, shale and boiler ashes? The class of substance was, he believed, rather important. He came across a case the other day in which it was proposed to use crushed shale in an operation of this kind, and it was subjected to laboratory tests in its dry crushed state. He had some figures of the actual weight applied and, taking what would be the equivalent to the depth and weight of strata from the surface, it would work out as follows: at 100 feet of depth the crushed shale gave a settlement of 12 per cent.; at 1000 feet 33 per cent.; at 2000 feet (or an equivalent pressure of 2000 feet) 39 per cent. When that crushed shale was mixed with 40 per cent. of sand under the same conditions the 12 per cent. was reduced to 4·3; the 33 per cent. to 12 per cent.; the 39 per

cent. to 15·8 per cent. It was quite evident, therefore, that the substance available was going to have a very material bearing on the result, and if they were going to have anything like 35 per cent. subsidence, the statement made on page 291 would require some modification, especially if it was to be employed in a thick seam. As to the reference to Koenigen Louise (Silesia) output on page 308 ('1000 tons and over from a 200 yards face'), it would be interesting to know the thickness of the seam. **The President.**

Mr. PATON : Two metres. **Mr. Paton.**

The PRESIDENT replied that they themselves had plenty as thick, but he was afraid that generally they did not get as good a concentrated output as that. Could the authors also give any information as to the increased volume of water required at different gradients with these materials?—again an important practical question. They had to pump the water, and would want to know how much extra they would have to pump, say, on a gradient 1 in 11 as compared with 1 in 5. **The President.**

Generally, he was a believer in the system, of which he had had a little experience on a small scale, but he saw difficulties in applying it generally to South Wales. To start with, he did not think they had anything like the material for any general application. He had always felt that if it could be applied on some of the main roads of their collieries for a good width on each side they would save very materially in repairs, get tight gobs on each side, and very much improve ventilation. He thought it might be feasible on those lines, because he did not think they could adopt any hydraulic stowing that would place no extra cost on the coal; but, dealing with only a portion of a colliery, it might be possible to spend something on the main roads, to obtain certain advantages, such as ventilation, etc., and spread it over the whole of the cost. He knew of a case in which, with difficulties of ventilation in long

The President. roads, they were suffering a loss of something like 60 per cent. by air leakage between the pit and the working faces. As a result they were seriously considering whether it would not be worth while, even at considerable expense, to stow their main roads or their main ventilation roads, to save that leakage. When it came to be worked out, it meant an increased cost on the working of the coal from those roads, which, spread over the whole colliery, seemed to be worth while. They were talking at a time when colliery people were not very willing to spend money on an experiment, but if the system could be tried by a combined effort—by every colliery contributing to the cost of a test on a suitable property—a good deal of information might be obtained. It had occurred to him that perhaps the Institute might be able to do some good work in that way through a committee, because it was undoubted that if they could hit upon something that would help them to reduce the cost of the maintenance of roadways in that field they would have made a big step forward.

Prof. Knox. Professor KNOX, replying to the discussion, said, speaking on behalf of Mr. Paton and himself, he was pleased to acknowledge the very cordial way in which the Institute had received this controversial subject. As a matter of fact, for the last fourteen years they had been attacked and buffeted for suggesting that such a scheme was at all possible in this country. At one time they had come to the conclusion it was because the method had been developed in Germany that there was such bitter opposition in this country, but after they had shown that every other coal-mining nation in the world except our own had adopted the process that argument could not hold. They had often wondered why everybody who rose to discuss the question always started on the assumptions, first, that the cost would be so excessive that it would be impossible to use it, and, secondly, that the number of diffi-

culties it would bring in its train were such as to rule it out of all economic discussion. **Prof. Knox.**

To deal with the questions in their order: Mr. Wales had asked if the method could be usefully applied in that district. That was just what they wished to get to know, and he might mention that six years ago, at a meeting in the Institute at Cardiff, and before a large number of coalowners, he put forward the suggestion which the President had been good enough to make at the end of his remarks, that the cost of the test installation, spread over the whole coalfield, would not amount to $\frac{1}{10}d.$ per ton on the total output, so that if unsuccessful it was worth trying, while if it were successful the company on whose colliery the test was made could pay the total cost, because they would receive the advantages, and it would cost the Association nothing. But they had some trouble in the coalfield then, and as they had not got through it yet, and did not seem likely to do so for some time, it was not a very hopeful moment at which to bring forward a proposition that would involve extra expenditure. But looking at the question from the point of view of their own experience of the system in other countries, he could not see anything that would militate against its success here, because, as he had pointed out, he had seen it applied in conditions much worse than any he had ever seen in a British colliery so far as effect of water on the strata, depth, timbering and difficulties in dealing with water were concerned. He had seen it applied in conditions quite as bad as if not worse than anything he had seen in this country. Of course, one had to admit that in this country, as in Germany, Belgium, and elsewhere, the system could not be applied to all mines successfully; for example, to mines that had been in existence for a very long period; but it could be adopted in any colliery just commenced, because there the initial expenditure would be very much less, as it

Prof. Knox. would be possible to lay out the work at the commencement with a view to its adoption as cheaply as possible. Mr. Wales said there were many things to be taken into consideration before coming to a decision. That was quite true, but they had to remember that there were behind us twenty-two years' experience all over the world. When the system was first started there was, of course, considerable trouble, but mining groups like Krupps, Gelsenkirchen and Deutcher Kaiser had spent enormous sums of money in experiments to find the best mixture, the best materials, the best kind of pipelines, the best methods of preventing choking and airlock in the pipes, etc. All these aspects had now been carefully studied, and difficulties arising from them were very rare.

One of the chief advantages of the system was referred to by Mr. Wales when he alluded to the amount of coal that now had to be left underground when collieries were under towns and villages, particularly under towns. In some parts of Scotland whole towns had been ruined. They would have an idea what a town like Hamilton was like with five seams underneath, varying in width from 3 feet 6 inches to 11 feet, extracted on the pillar-and-stall system, when the last seams were completed. Whole streets had been demolished at a time, and the cost to the municipality in upkeep of roadways and their public services—gas, water, etc.,—was enormous. In a case like that, he thought there could be no question at all as to the economic advantages of a system such as hydraulic stowing. As they got away from the crowded areas to the agricultural, the advantages from the point of view of subsidence would, of course, become less and less. The other point Mr. Wales mentioned was spontaneous combustion. He believed the chief reason for the initial development of this system was the prevention of spontaneous combustion. It

was first adopted on a large scale in very thick seams in Silesia, from which had arisen this modern engineering development. There they had enormous trouble, something like what had been experienced in South Staffordshire. A very large portion of the coalfield had been on fire for some years, and the danger of working was so great that they were only too glad to adopt any kind of scheme that would get rid of it. There was one thing that could be said : in no case in which hydraulic stowing had been adopted had there been a gob fire afterwards, and there was no colliery he knew of which, having adopted the system, had not continued to use it. It had never been abandoned in any case so long as the colliery continued to work. **Prof. Knox.**

As to Mr. Dyer Lewis' remarks, everybody seemed to agree in thinking the system ought to be tried as an experiment. He suggested that somewhere on the South crop, where they were close to a good supply of sand—which, of course, they could get anywhere practically from Bridgend to Swansea—would be the best place for a trial plant ; and if this could be arranged in the way he suggested four or five years ago, with the backing of either the whole of the collieries on the South crop or the whole coalfield, the cost would be very trifling if it had to be abandoned ; while if it were successful it would cost the guarantors nothing. The arrangement would be merely a guarantee fund to the colliery company testing the scheme. In working the steam coal measures the excavation, as Mr. Dyer Lewis had said, caused an enormous amount of difficulty and increased the amount of timbering required in the mines by 100 per cent. above what would be required if a better system of packing could be adopted. Supposing they could save 50 per cent. of the timber at present used in their steam collieries, that would save a sum which, he should say, would be practically equivalent to the cost of running an installation of this kind. It would have been more than sufficient before

Prof. Knox. the war. What the cost of such a system would be was rather difficult to estimate, but in Germany and Silesia they were working from as low as 6*d.* per ton up to 1*s.* 6*d.*, the figure depending upon the difficulty in obtaining the material required for stowing. In Australia they had the cheapest method in existence, because they had the whole of the crushings from the ores ready at hand in a fine, repulverised state, and these were flushed right back down again at a cost of something like 2*d.* per ton of material raised. By adopting the method there would certainly be, as Mr. Dyer Lewis suggested, less loss of coal, because the whole seam, or the whole thickness of seam worth extracting, could be taken. Mr. Roblings' point as to through coal was, he thought, a departmental one. In regard to steep seams and the use of this system, the amount of water required was less than in others. The President also raised this question, and he had found, taking fourteen places from which he had obtained particulars—some of them working main roads up to 4400 yards—the ratio of horizontal distance to vertical head was about 2 to 1 for a 1 to 1 water supply (i.e., 50 per cent. water and 50 per cent. debris). Where the horizontal distance to the vertical head was 3 to 1 the amount of water required was twice that of the material packed. Where the horizontal distance was 5 to 1 the amount of water required was 4 to 1. The cases where there were such long distances from the shaft to the working vein where the packing was being carried out were due to the fact that they were old mines laid out for this system under very adverse conditions. It would not be necessary in many cases to have such long horizontal lengths of pipe to carry the material.

Mr. Davies referred to the difficulties of the anthracite seams as being against the adoption of a scheme like this, and asked also, could it be done economically? Well, that depended

Prof. Knox.

upon the kind of plant adopted; upon how cheaply they could get their material; depended on their underground conditions —depended on so many things that one could only give a general impression. In Belgium they were using the hydraulic method where conditions were just as awkward as it was possible to get them—on seams from 2 feet 9 inches to seams which, normally only 3 metres thick and sometimes nearly pinching out, got to 45 metres on the bends. And they found it cheaper to deal with all their workings than to confine packing to the thin seams only, the same pipe line supplying packing material to all the seams as the work proceeded. The squeeze referred to by Mr. Davies would be reduced considerably if the gob were packed in this way. Mr. Paton referred while showing the slides to one roadway that was driven through the packing. He saw that operation being carried out, and it was quite true that it had to be blasted. The force of water carrying the material got the particles embedded so very solidly together that if they could make a proper division of their materials—i.e., if they could by a certain process get material of all sizes from two inches centre downwards into the pipes—they could get the excavations almost as securely packed as nature had done when stratification took place. The loss in subsidence would be the amount lost from water squeezed out—that was all.

As to Mr. Roblings' point—the water percolating through the floor—that could, of course, be caused even by roof squeeze. In this coalfield it was a very peculiar feature that they got a great deal of water coming from north of the coalfield through the layers underlying the coal measures and breaking out through the lower seams. This occurred practically all over the coalfield and, of course, hydraulic stowing would not help that in any way, while considerably adding to troubles in dealing with the water. But the cost of pumping was not

Prof. Knox. such an enormous factor if they could make a saving in the cost of working the coal by the application of machinery for cutting and conveying and hydraulic packing ; by getting the material packed as quickly as they worked, because that was, after all, the way to reduce subsidence, and the reduction of subsidence would more than cover any increased cost of pumping. Another point was the objection of the miner to working in damp conditions. In some districts, particularly in the Rhondda, he should say the men would be delighted to get such conditions, just for a change, because there they had the coal dust difficulty, which was even worse than the one of dampness, with everyone breathing about as much dust in three or four hours as would make a small briquette ! It was quite true that small outputs would not be conducive to economical working, because they would have to bear both initial cost and maintenance costs, and it would certainly pay better to instal it where it would enable them to get a large output such as referred to by Mr. Paton.

The President raised one or two very interesting and practical points. The proportion of the gravitational stresses on the packs was the total amount of overlying weight. There was nothing else it could rest on ; it had to rest somewhere, and it could rest only on the packs. But the amount of pressure they might get was determined by the distance they allowed it to drop and the time in which they allowed it to drop. If they worked coal quickly and packed closely behind, the amount of drop was very little and they saved all that cracking of the roof, forcing off pieces into the working, that was commonly associated with any slow method of working coal seams. That was the most marked feature of the large seams where the system was in operation. He had taken several parties across to see, among other things, this system in operation, and they were all amazed at the enormous amount of roof exposed without

support at the face, and could not understand it. But it was due to the fact that the protection was over a very long distance. The better they packed, the further beyond the face did they force the line of fracture, if it fractured at all. Therefore the total amount of support required on the part of the gob next the face was reduced considerably. They could see on one side of a mine strips of hydraulic packing put in as far apart as the walls of that room and in the other side of the same pit where they were still continuing the old system supports put up as little as 2 feet to 3 feet 6 inches apart, with falls of roof continually occurring. He quite agreed with the President that supposing they decided on a test and did not make it through the whole workings, but only on the roadways, it would save a very large cost, not only in re-timbering but in the initial cost of timbering. **Prof. Knox.**

With regard to settlement, the President referred to a case in which the mixture of sand with the shale gave very much better results. That had been found to be the case at Gelsenkirchen with crushed slag and sand, the slag being broken to about $1\frac{1}{2}$ inch mesh and mixed in the proportion of 7 to 3 of sand, so that the sand filled up the interstices between the rougher pieces of slag. That made an excellent packing, free from any sludgy matter, which was difficult to extract from the water underground, and was easily carried in the pipes without sticking. He had already referred to the volume of water required. Certainly improvements in ventilation were quite apparent in all those mines where the system had been adopted. In many Welsh mines they lost as much as 60 per cent. of the air before it reached the face; in mines where hydraulic packing was used no such leakage was taking place, and it was considered bad to lose 20 per cent., and that was practically confined to the usual stoppings, doors, etc.

Also replying, Mr. PATON pointed out that at Koenigen Louise the stowing of 2000 tons was done in six hours, and **Mr. Paton.**

Mr. Paton. that there three days' work and then one of stowing was done. This was the finest example of stowing known, and it was secured at a property which had also the record of 1000 tons of coal broken from a 200-yard face in twenty-four hours. And as to gob fires, there were mine managers in Silesia who formerly never slept all night, and who, after the stowing system was put in, did not know what it was to be in the mines so far as fires were concerned. Air supply had improved, and applying the principle to endangered pits they had started hauling again. In conclusion, he wished to compliment the Society on the excellent way in which the paper had been recorded in the Transactions, thank the Secretary for the kindness he had received, and express his pleasure at having had the privilege of coming before them.

The President. The PRESIDENT thought the meeting would agree with him that they were much indebted to Professor Knox and Mr. Paton for this very interesting and valuable paper, which had given rise to a practical discussion. He hoped some good might result from it. He apologised to Professor Knox for having repeated a proposition which he apparently made some years ago and of which he was not aware. He asked them to pass a hearty vote of thanks to the authors.

The vote was warmly accorded.

The Froth Flotation of Coal.

BY FRANK BUTLER JONES.

(FOR PAPER, *vide* PROCEEDINGS, Vol. XXXVII., No. 4, p. 331.)

Mr. F. Butler Jones. In giving a synopsis of his paper the Author said his paper was written six months previously, so was not quite up to date, but he did not think there had been any development since of sufficient importance for him to lay stress upon. He would like to make an addition on page 363, where he had given

some second-hand information without acknowledging its source. The information contained in the paragraph commencing 'The advantages attendant upon the use of such coke in iron blast furnaces are very great' was published in a paper by Bury, Broadbridge and Hutchinson called 'Froth Flotation as applied to the Washing of Industrial Coal,' in the *Transactions of the Institute of Mining Engineers*, Vol. 60, Part 3.

Professor KNOX complimented Mr. Butler Jones on his paper, which he thought very up to date, notwithstanding its having been written six months ago. This question of coal cleaning was an exceedingly important one, not only from the point of view of making metallurgical coke, but also in making other materials, such as smokeless fuel, which could be of greater use converted into that form. Many of the coal seams in South Wales were, of course, too dry to be of much use for any kind of coking process, but within recent years—recent months, as a matter of fact—various organisations had been working on this problem of the conversion of coal into smokeless fuel, and in one case at any rate it had been very successfully carried out. And the system that Mr. Butler Jones had outlined of washing very fine coal that perhaps could not be washed with any other washer except the Draper, if it could be carried to the degree of fineness outlined, was certainly a very valuable adjunct to their mining processes, because everything that tended to save coal was going to help them at a time when things in this district were as black as could be, blacker than anywhere else in the country. If they had engineers like Mr. Butler Jones coming forward to help them make better use of the product, they might hope in the near future to get back to normal conditions. There was a point that struck him in the paper with regard to the degree of fineness at which coal might be washed. This undoubtedly opened a very wide field for some of their chemists and **Prof. Knox.**

Prof. Knox. engineers in the matter of making other products from coal which up to now had been exceedingly costly. As a matter of fact he believed all the electrodes now had to be made from pitch coke, which was a very slow process and a very costly one. If they could get coal clean enough for a process like this, washed to a degree of fineness that the amount of ash would not destroy the cohesion of the carbon, that would provide them with a method of making these electrodes at a cost of perhaps not more than 50 per cent. of that required to-day. It would be one outlet for anthracite duff if they could get it sufficiently clean and fine. Some of the anthracite seams contained very little ash. They wanted not more than 1½ per cent. ash, so that if they could get the coal clean enough it could be used, as Mr. Butler Jones suggested, for that purpose.

Mr. Paton. Mr. PATON mentioned his interest in electro carbon and his introduction of it to the nation. They recovered carbon from pitch, the price ruling at about £12 to £14 per ton. The whole difficulty was the securing of the carbon. He understood it was used to a considerable extent in the aluminium industry, and that there was a movement towards using aluminium to an extent which would depend upon pitch coke or carbon of this type. The electrical industry was also developing. The aluminium interests particularly required a coal with only 1 per cent. of ash, while the steel industry could take it giving up to 5 per cent. to 7 per cent. of ash, so it was for colliery owners to look seriously into these processes. His experience in washing was that the trouble commenced below ¼-inch mesh.

The Secretary read the following contribution from Mr. JOHN M. DRAPER:

Mr. John M. Draper.

I am extremely sorry that I am unable to hear Mr. Jones' paper on the above subject.

We are all interested in economics at the present time,

and in South Wales particularly in that connected with the saving of fine coal. Mr. John M. Draper.

I think Mr. Jones has handled the subject with commendable clarity and brevity, and has given us a thoughtful paper, which should provoke a good discussion.

The principles underlying this subject are outside the usual range of study of the practical man. They deal with the minute forces in nature, and with little understood reactions.

The literature of flotation methods teems with such terms as 'molecular adsorption,' 'interfacial tension,' 'hysteresis,' 'Brownian movement,' etc. It leads us to reflect, for example, on the laws governing the travel of tiny spheres of water running on the clear surface of a pool, and the mystery of tiny bodies of high gravity being carried upward by air bubbles in utter defiance of gravitational fall. The question of practical application immediately arises.

It is clear from the Author that the factor of size must for all time present a serious limitation to the usefulness of the process. This size is given as from 0·0833 to 0·125 inch linear dimensions, over which the process is inoperative.

Recent experience has proved that by simple hydraulic separation coal very much below these dimensions can be successfully washed down to the fixed ash, without the aid of agitators or reagents.

Down to 60 mesh wet gravity separation is a perfectly practical proposition, giving sharply defined products equal to laboratory separations on gravity solutions. Below these sizes there are problems of dewatering involved, which with diminishing fineness become extremely difficult, and are of course common to all systems.

There is no question that froth flotation will separate very fine coals from dirt, and that there is ample room and scope for dealing with certain fine materials; but will it be able to

Mr. John M. Draper. handle large quantities more economically than other systems ?

At what point will the increased viscosity of re-used water affect the flotation ?

It seems to me that the success of the flotation process depends upon extremely fine and somewhat costly grinding, coupled with entire elimination of oversize, or that critical size of particle ranging between $\frac{1}{8}$ inch to $\frac{1}{12}$ inch mesh or less which is *not* carried up by the air bubbles, as well as the absence from the coal of pyritic sulphides, which *are* floated.

Following this must come the development of a practical dewatering device, and finally the definite establishment of a better class of operator than is usually found at a coal washery.

Particularly is this latter important where the process depends on complex and little understood reactions.

The rest is a matter of pure economics.

The field is large, and there is ample room for another process to separate fine coal from dirt, provided it can be done efficiently and economically.

Mr. George Roblings. Mr. Roblings said there was little he could add to the paper. The difficulty in washing small coal was very great. There was no question that as far as anthracite duff was concerned the difficulty was in screening as low as they would like to carry it. They would like to get the palpable dust out in order to use the grains, no matter how small, for some definite purpose, such as boiler firing or something of that kind, owing to the fact that the dust was carried over with the draught into the flues, causing considerable hindrance. The washing of the small particles was a problem that would have to be tackled in the future, after solving that of screening the duff to that degree of fineness. Crushing, if required, was a difficult question, by no means the same kind of problem with anthracite as with small steam coals. In that connection he would

refer them to the class of experiments carried out at Alltofts by Mr. W. W. Hood and others. With regard to ash in the anthracite duff, he did not think that problem was quite so easy, or the percentage quite so small, as Professor Knox had just suggested. He remembered some years ago getting some tests made on fine anthracite. Dust of $\frac{1}{30}$th inch was passed into the water for the purpose of testing how much ash could be separated; the ash percentage prior to washing was 13 per cent. and there was 13 per cent. of ash in the washed coal, which amounted to nothing more or less than the whole lot floating on the top of the water during the *agitation*. So there was room in the anthracite field for an efficient washer of the type Mr. Butler Jones had described. **Mr. George Roblings.**

Mr. PATON asked what was the smallest size worked to in screening. **Mr. Paton.**

Mr. ROBLINGS replied that the smallest they were able to do was $\frac{1}{8}$th. **Mr. Roblings.**

Mr. PATON said that if Mr. Roblings would look into the question of percussion screening as given in his paper on 'Dust Treatment,' he would see details of the Weissmann-Humboldt system which he had applied and extracted successfully from $\frac{1}{64}$th up, the sizes $\frac{1}{64}$th to $\frac{1}{8}$th being mixed with coking coal after washing. **Mr. Paton.**

Mr. ROBLINGS replied that the difficulty was the damp coal. That blanketted the meshes, etc., for some considerable time afterwards. **Mr. Roblings.**

Mr. PATON explained that if the small stuff was put into a drier, as was the practice before he left Germany, the $\frac{1}{64}$th and over was absolutely taken out and that stuff was analysed for ash. Other small was put out for briquettes. **Mr. Paton.**

The PRESIDENT said he proposed to adjourn the discussion to the next meeting, as perhaps there were more people interested in the washing of coal in the eastern portion of the coal- **The President.**

The President. field than in the western. He would like to thank Mr. Butler Jones for coming there and giving his interesting paper.

He also proposed a vote of thanks to the coal owners of the western portion of the coalfield for the use of the room.

Mr. Roblings. Mr. ROBLINGS remarked that it was felt that the interests of the coal owners were so intertwined with those of the Institute that the use of the room was most readily granted.

Mr. H. T. Wales. Mr. H. T. WALES seconded the vote of thanks, and this having been accorded the proceedings terminated.

Causes of Subsidences and the Best Safeguards for their Prevention.

BY R. C. MORGAN.

(For PAPER, *vide* PROCEEDINGS, Vol. XXXVII, No. 1, p. 49.)

Discussion.

Mr. H. W. Halbaum. Mr. H. W. HALBAUM wrote: In the last-issued Part of the *Proceedings* I see that the discussion on this paper is closed. But I presume the Council will allow me another word since, in the same Part, I notice that Mr. Morgan 'would like to know what grounds Mr. Halbaum has for making this statement,' namely: that the lateral thrust is largely a spent force in South Wales.

Mr. Morgan says that, personally, he favours Principal Knox's theory of the effect of the 'unbalanced loads due to the hills.' If that is so, he has only to ask himself now: In what respect, other than in the respect of lateral thrust, are these loads 'unbalanced'? If you take away the hills, you remove the greater part of the surface of South Wales, but not all of it. Hence, I content myself with saying that the lateral thrust is 'largely' a spent force in this locality. The 'recent deep sinkings' quoted by Mr. Morgan, although he appears to have

missed their significance, prove the poverty of the lateral force rather than otherwise, since they show the inefficiency of the circle of the shaft considered as an arch—the arch lacks the consistency which can be imparted only by lateral pressure, and cannot therefore support the vertical thrust, with the result that it runs or tends to run like a semi-fluid under a vertical head of pressure. Of course, he was not likely to hear 'that the squeeze on the workings was any the less in consequence.' Quite the contrary. **Mr. H. W. Halbaum.**

But the evidence is not confined to the configuration of the surface. It is confirmed and corroborated by the testimony underground. In other coalfields you find cleavage planes induced by lateral pressure. But to separate the coal on one side from the coal on the other side of any given cleavage plane requires the expenditure of a considerable amount of force. In South Wales, on the other hand, you get a regular system of 'backs' and 'slips,' which are, from the standpoint of this discussion, practically open joints. What appreciable lateral compression can you have between open joints a yard or even two yards apart ?

These open joints evidence three distinct happenings. In the first place they show that at one time the strata were under great compression. Secondly, that the direction of the compressing forces was at right angles to the plane of the 'backs.' Thirdly, that the strata finally found relief by extension, and that it was this extension which opened the joints to the extent we now see. Hence, the lateral force originally obtaining has now practically exhausted itself.

To understand why it was possible for the lateral force to exhaust itself in South Wales, and not possible for the same force to exhaust itself in the North, nor in the Midlands of the sister country, is quite easy after a little reflection. There are certain factors connected with the Malverns and with the

Mr. H. W. Halbaum.

Mendips which I have not been able so far to place in their proper order of importance, though I feel sure that those factors exist as factors and that they will presently come clearly into view. Even so, the case is fairly clear without them, having in view only the particulars of structure which any man may see for himself in connection with these ' backs ' in the South Wales strata.

Next, let it be understood that the lines of cleavage in the Northern coalfields of England lie in planes which are vertical or nearly so. Hence, the lateral pressures associated therewith are horizontal or nearly so. That is, they react against the almost infinite resistance of miles of strata in the horizontal or nearly horizontal plane. Hence, except near the outcrop, where the vertical pressure is also comparatively small, there can be no relief from the lateral force except that afforded by mining operations.

In South Wales, the case now, whatever it may have been formerly, is that the plane of the ' back ' is deflected from the vertical by thirty, forty-five, or even sixty degrees. Therefore, the lines of the ancient pressures which produced it are now deflected from the horizontal by thirty, forty-five, or even sixty degrees. And therefore, *those lines now run out at the surface.* Hence, the lateral compressive strain formerly existing in the upper strata has now been relieved, simply because the compressive force on one side of the ' back ' is no longer balanced by an equal compressive force on the other side of the ' back.' The result is that whilst, in the North of England, the upper strata still form an arch with all its bricks *in situ* and its keystone in position, in South Wales the keystone has been removed and all the bricks have parted company, as seen by the open joints, ' backs ' and ' slips ' which form such a unique and characteristic feature of the South Wales coalfield. That, in my opinion, is the price South Wales pays for its scenery,

and that also is why the theory I framed for the North can have small practical application in the South. Mr. H. W. Halbaum.

As for Mr. Morgan's remark that 'it is evident these falls of roof cannot extend above the neutral zone,' it implies that he has not sufficiently studied this part of the subject. The phenomenon of the neutral surface which constantly retreats as its outposts are driven in is a most important part of the theory. In fact, the cantilever idea cannot be properly understood until one has completely grasped the fact that the neutral surface in this case is essentially a *shifting* surface. And a shifting surface it must always remain so long as the effective beam continues to be planed down unequally on opposite sides. If it were otherwise, it would be possible to divide a beam 12 inches deep into two beams each 6 inches deep, one of which would have its neutral surface on the very top, and the other of which would have its neutral surface on the very bottom of the beam. Which, of course, is absurd.

ON THE ORIGIN OF ANTHRACITE.

By W. Galloway, D.Sc.

ON THE ORIGIN OF ANTHRACITE.

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In the first part of the course of lectures on mining which I had the honour of delivering before the members of this Institute in the first year of the present century, entitled 'The South Wales Coalfield,' I referred to the decrease in volatile matter in the seams of coal which takes place between the south-east and north-west of the coalfield.

In attempting to account for this decrease, I suggested that the change was probably due to the fact that the north-western end of the coalfield was at one time covered by a much thicker series of deposits than the south-eastern end, and that the deposits overlying the ground in the intervening space thinned gradually from north-north-west to south-south-east, with the result that the seams lying at greater depths under the surface would, while that condition obtained, be exposed to a higher temperature than those lying at a less depth, and that decomposition would proceed more rapidly in the former than in the latter. I mentioned, further, that it is the universal experience in all coalfields that, other things being equal, the deeper seams are less bituminous than the shallower seams.

In a memoir published by the Geological Survey in 1915,* Sir Aubrey Strahan, lately Director-General of the Survey, questioned the validity of this explanation (p. 75), and therefore I think it may be useful to cite some further information

* 'The Coals of South Wales. With Special Reference to the Origin and Distribution of Anthracite.' Second Edition, 1915.

obtained from borings in Kent and at Pembrey, near Kidwelly, which seems to corroborate my views.

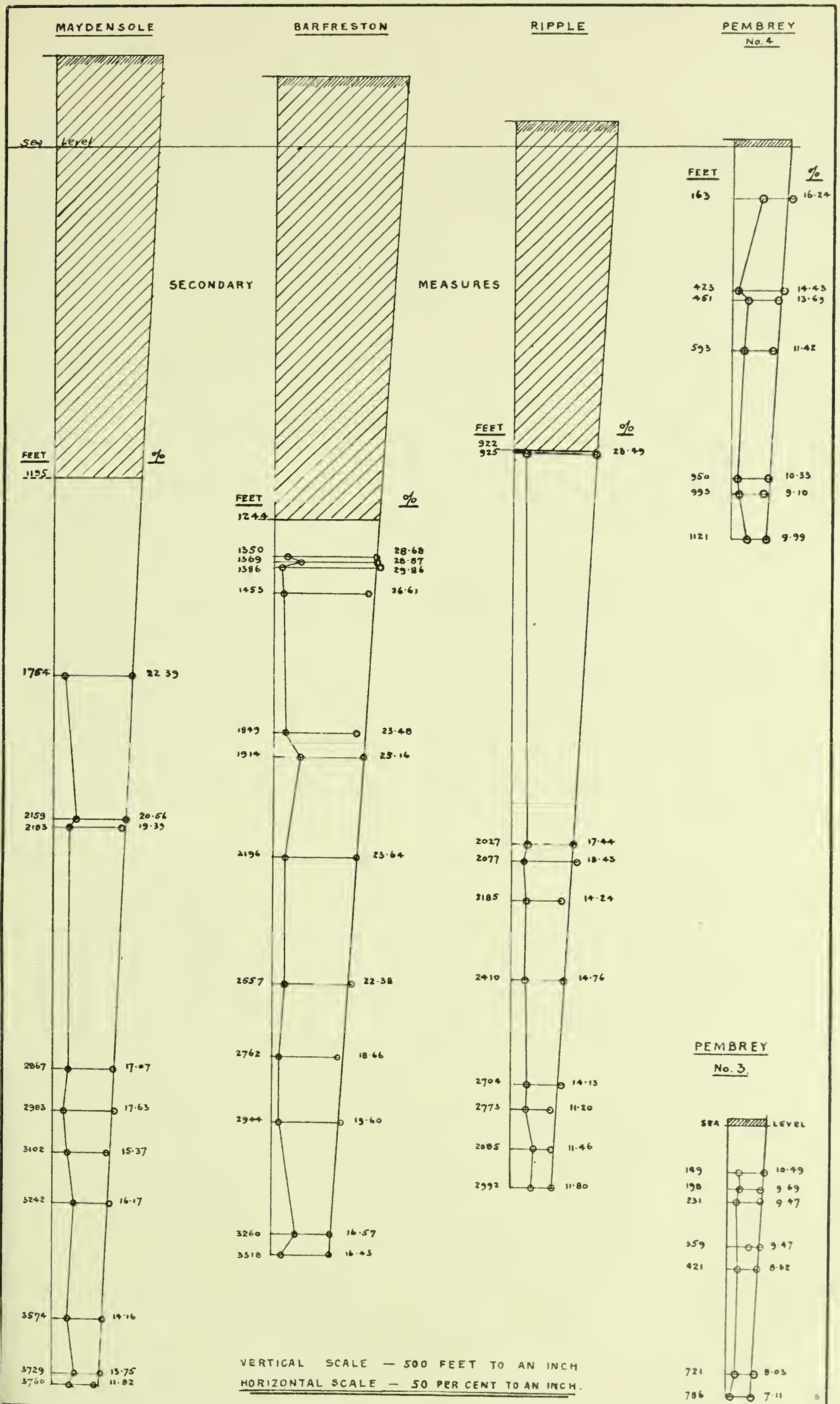
With this object I have constructed the five accompanying diagrams—three of the Kent boreholes, Maydensole, Barfreston, and Ripple, and the two Pembrey boreholes, Nos. 3 and 4.

In each diagram the depths of the seams below the surface are shown by means of figures at the left-hand side; the percentage of volatile matter, less ash and moisture, is shown by means of figures at the right-hand side; and the percentages of ash are shown by means of small circles whose centres are at the required distances from the right-hand side of the vertical line measured on the scale of 50 per cent. per inch.

The principal results contained in the diagrams are summarised in the following table:

Borehole.	Highest Seam.		Lowest Seam.		Difference in Depth.	Difference in Volatile Matter.	Average Depth for 1 per cent. decrease in Volatile Matter.
	Depth.	Volatile Matter.	Depth.	Volatile Matter.			
	Feet.	Per cent.	Feet.	Per cent.	Feet.	Per cent.	Feet.
Maydensole .	1754	22·39	3760	11·82	2006	10·57	189
Barfreston . .	1350	28·68	3318	16·43	1968	12·25	160
Ripple . .	925	23·49	2992	11·80	2067	11·69	176
Pembrey, No. 3 .	149	10·49	786	7·11	637	3·38	188
,, No. 4 .	163	16·24	1121	9·99	958	6·25	153

The analyses of the seams found in these boreholes seem to prove: First, that there is a gradual and practically uniform decrease in volatile matter with depth; secondly, that the proportion of ash has no special connection with the decrease in volatile matter; thirdly, that, other things being equal, the deeper the seams lie under the surface the more nearly does their chemical composition approach to that of


MAYDENSOLE
BARFRESTON
RIPPLE
PEMBREY No. 4
SECONDARY MEASURES
Sea Level
FEET
%
1195
1784 22.39
2159 20.56
2183 19.39
2867 17.07
2983 17.63
3102 15.37
3242 16.17
3574 14.16
3729 13.75
3760 11.82
1244
1350 28.68
1369 28.87
1386 29.86
1455 26.61
1849 23.48
1914 25.16
2196 23.64
2657 22.38
2762 18.66
2944 19.60
3260 16.57
3318 16.43
922
925 28.49
2027 17.44
2077 18.43
2185 14.24
2410 14.76
2704 14.13
2773 11.20
2885 11.46
2992 11.80
163 16.24
423 14.43
461 13.69
593 11.42
950 10.33
993 9.10
1121 9.99
PEMBREY No. 3.
SEA LEVEL
149 10.49
198 9.69
231 9.47
359 9.47
421 8.62
721 8.03
786 7.11
VERTICAL SCALE — 500 FEET TO AN INCH
HORIZONTAL SCALE — 50 PER CENT TO AN INCH.

anthracite (88 to 95 per cent. of carbon); and fourthly, that the casual occurrence here and there of a seam containing more volatile matter than one, or more than one, of those above it, does not in any way invalidate the first of these four propositions, but must be attributed to causes into which we need not here inquire.

I am in accord with two of Sir Aubrey's summaries given at p. 81 of the memoir, viz. :

(1) 'The anthracitic character was not due to faults, but existed before faults were formed.'

(2) 'The anthracite existed as such before the coalfield was reduced by denudation to its present dimensions.'

I am disposed to think, however, that all mineral matter of organic origin is continuously undergoing degradation, and that possibly both the anthracitic and bituminous seams had reached a much less advanced stage of decomposition than that in which we now find them at the time when denudation had succeeded in exposing them to the same relative extent as at present.

I might perhaps be allowed to take this opportunity of expressing the regret I have always since felt that, in the early 'eighties of last century, I maintained, without sufficient investigation and with little more than rumour to guide me, that the steam coal seams below the Nine Feet, which were not being worked and were hardly known at that time, were less valuable than the Nine Feet and those above it, and that their quality was probably no better than that of ordinary coals from any other part of the country. A very few years' working of these seams proved the erroneousness of this view, which I now desire openly to recant.

BOILER HOUSE MANAGEMENT.

By David Brownlie, Member, B.Sc.Hons. (Lond.), F.C.S., A.I.Mech.E., A.M.I.Min.E., Mem.Am.S.Mech.E.

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I have been honoured by the Council in being asked to read this paper before you on 'Boiler House Management,' under the special headings of:

(1) Types of boilers, with their relative advantages and disadvantages.
(2) Mechanical stoking.
(3) Economisers and feed-heaters.
(4) Superheaters.
(5) Forced and induced draught.
(6) Auxiliary machinery, including conveyors, feed-water pumps, etc.

The term 'boiler house management' can, I think, be said to mean all that is necessary for economical steam generation in the boiler house, and comprises two distinct sections, namely, management in the sense of efficient design and equipment of the boiler plant, and management from the point of view of scientific methods of control of the working of the plant, so that the best results are being obtained. That is to say, a boiler plant is like any other machine, appliance, or instrument, and in order to obtain the best results it must first be of sound design and workmanship, and must then be operated with skill and intelligence.

It is not at present generally realised throughout the world that boiler house management is an important, interesting, and intricate branch of applied science, and that in

most industries there is more money to be saved in the boiler house than in any other section of the establishment.

I think it will be advisable here to give some statistics

GREAT BRITAIN.

(Average annual figures, which will probably apply more or less to the next few years.)

Coal Production . . . . 250,000,000 tons.

Coal Disposal—

	Tons.	Per Cent. of Total Coal raised.
(A) *Exported*, 25 *per cent., as follows:*		
1. Sold to the colonies and foreign countries	41,875,000	16·75
2. Sold to ocean-going steamers . . .	13,750,000	5·50
3. Sold to foreign countries as coke . .	3,125,000	1·25
4. Sold to foreign countries in the form of manufactured fuel (briquettes, etc.) .	1,875,000	0·75
5. Sold to coasting steamers	1,875,000	0·75
Total	62,500,000	25·00
(B) *Home Consumption*, 75 *per cent., as follows:*		
6. Steam generation:		
(*a*) power purposes	60,000,000	24·0
(*b*) low pressure purposes	30,000,000	12·0
7. Domestic	35,000,000	14·0
8. Coke from coke ovens	20,000,000	8·0
9. Gas works	18,000,000	7·20
10. Railways	15,000,000	6·0
11. General purposes	9,500,000	4·80
Total	187,500,000	75·00

relating to the national fuel question, and of the enormous amount of money there is to be saved in Great Britain by the adoption of modern methods of boiler house management. As I have stated on various occasions, we are badly in need

of a proper engineering census of the country, but until more detailed information is available, I think the simple 'balance sheet' of the coal question for Great Britain on p. 406 will not be far wrong—that is to say, we consume in Great Britain 90,000,000 tons of coal per annum, being 36 per cent. of the coal raised, or 48 per cent. of our home consumption, for the one operation of steam generation.

There has not hitherto been much data available as to the results being obtained in practice in boiler houses, and the saving to be realised by adopting modern scientific methods of boiler house management. Most of the data seems to apply to special tests carried out under abnormally good conditions with high quality coal, and I am afraid that some of this data is hopelessly inaccurate as applied to the ordinary everyday boiler house practice in burning practically the whole of the 90,000,000 tons per annum.

Donkin, in his book on 'Heat Efficiency of Steam Boilers,' gives 50 tables, containing the results of 425 experiments on different boilers. The results as given in this book are summarised in Table A, p. 408 (being for the boilers only without economisers).

Very great variations were met with, and, for example, as seen in the 107 tests on 'Lancashire' boilers, the efficiency varied from 79·5 per cent. to 42·1 per cent.

It will be noted that these results are without economisers and superheaters, so that some of the figures can only be described as extraordinary.

Many boiler tests have been carried out by Barrus in America, and the results of over 300 tests are given by him as in Table B, p. 408.

W. S. Hutton ('Steam Boiler Construction,' 1916) gives a number of figures for the performance of various types of boilers, 'which may generally be obtained in practice with

TABLE A.

Type of Boiler.	No. of Experiments.	Average Efficiency.	Average of Two Best Results.	Worst Result.
		Per cent.	Per cent.	Per cent.
Water-tube, $1\frac{1}{2}$-in. tube	6	77·4	84·1	66·6
Locomotive	37	72·5	83·3	53·7
Lancashire	10	72·0	74·4	65·6
Two-storey	9	70·3	76·1	57·6
Two-storey	29	69·2	79·8	55·9
Dry back	24	69·2	75·7	64·7
Return tube	11	68·7	81·2	56·6
Cornish	25	68·0	81·7	53·0
Cornish	9	67·0	81·0	55·0
Wet back	6	66·0	69·6	62·0
Elephant	7	65·3	70·8	58·9
Water-tube, 4-in. tubes	49	64·9	77·5	50·0
Lancashire	40	64·2	73·0	51·0
Cornish	3	62·7	65·9	60·0
Lancashire	107	62·4	79·5	42·1
Dry back	6	61·0	73·4	54·8
Lancashire, 3-flue	6	59·4	66·7	52·0
Elephant	8	58·5	65·5	54·9
Lancashire	8	57·3	74·3	45·9
Vertical	5	56·2	76·5	44·2

TABLE B.

Water evaporated from and at 212° per Pound of Combustible.	No. of Tests with Anthracite.	No. of Tests with Anthracite and Soft Coal.	No. of Tests with Semi-bituminous Coal.	No. of Tests with Bituminous Coal.
Over 12·0	2	2	45	3
11·5 to 12·0	2	—	37	2
11·0 to 11·5	7	7	45	7
10·5 to 11·0	17	7	44	7
10·0 to 10·5	9	3	24	3
9·0 to 10·0	6	3	7	17
8·0 to 9·0	2	2	2	5
7·0 to 8·0	—	1	—	3
Total	45	25	204	47

boilers having tolerably clean heating surfaces when fired with good coal,' as follows :

Type of Boiler.	No. of Tests given.	Evaporation, Pounds Water from and at 212° F.
Lancashire	22	8·25 to 12·02
Cornish	7	7·75 to 11·56
Egg-ended	6	6·52 to 8·56
Vertical	15	5·57 to 10·21
Water-tube	73	7·02 to 13·40

Again, some data supplied by Molesworth :

Description of Boiler.	Pounds Water from and at 212° F. evaporated per lb. Average Coal.
Egg-ended	8·0
Cornish	8·0
Lancashire	9·0
Water-tube	8·0
Ordinary marine . . .	9·5
Tubular	9·5
Locomotive	10·5
Torpedo boat . . .	13·0

Another ludicrous statement in a recent chemical pocket-book is as follows :

'The efficiency of a boiler should be as near to 80 per cent. as possible, this figure being considered excellent. A more usual figure is 70 per cent., which is quite good. The water evaporated from and at 212° F. per lb. combustible is a good indication of the efficiency of a boiler, and under normal conditions should be about 12 lbs.'

It is generally assumed to-day in great Britain that 1 lb. of average coal will evaporate 7–8 lbs. of water from and at

212° F., and for example many engine builders take the figure of 8 lbs. in calculating the steam consumption of their engines.

In my opinion, many of these figures are entirely erroneous, and seem to have been copied out of one book into another for years without any attempt at verification.

The firm with whom I am associated have been engaged continuously for the past twelve years or so in carrying out complete scientific investigations into the working of steam boiler plants, and we have tested nearly 500 plants, in addition to making an inspection of about 2,000 plants.

I have tabulated the detailed figures for the performance of 400 boiler plants (1908 to the present time) in 41 different industries, representing 1,513 boilers with a total annual coal consumption of 3,250,000 tons, and the average nett working efficiency of these plants is approximately 58 per cent., the highest being 82·21 per cent. and the lowest 32·50 per cent., whilst the figures can be sub-divided as follows:

Nett Working Efficiency.	No. of Plants.
1. 80 per cent. and over . . .	2
2. 75 ,, ,, . . .	9
3. 70 ,, ,, . . .	17
4. 65 ,, ,, . . .	58
5. 60 ,, ,, . . .	69
6. 55 ,, ,, . . .	96
7. 50 ,, ,, . . .	80
8. below 50 per cent. . . .	69
Total	400

I gave ('Coal Saving by the Scientific Control of Steam Boiler Plants,' *Engineering*, July 12 and 19, 1918) the true average figures for the complete tests on 250 of these plants (1,000 boilers and 2,166,000 tons annual coal bill) as follows:

AVERAGE OF 250 TYPICAL BOILER PLANTS.

(A) *Working Day's Test :*

Type of boiler	'Lancashire.'
Number of boilers	4
Grate area	152·6 sq. ft.
Duration of test	9·43 hours.
Amount of fuel used	30,131·72 lb.
Analysis of fuel used :	
British thermal units	11,822
Ash	11·5 per cent.
Fuel burnt per boiler per hour	798·8 lb.
Fuel burnt per square foot of grate area per hour	20·9 lb.
Water evaporated	197,776 lb.
Water evaporated per boiler per hour	5,243 lb.
Water evaporated per square foot grate area per hour	137·4 lb.
Water evaporated per lb. fuel	6·56 lb.
Equivalent evaporation from and at 212° F. per lb. fuel	7·46 lb.
Equivalent evaporation from and at 212° F. per 1,000,000 British thermal units	631·0 lb.
Temperature of feed-water before economiser	116° F.
Temperature of feed-water after economiser	193° F.
Percentage of fuel bill saved by economiser	7·1 per cent.
Draught in side flue	0·40 in W.G.
Draught in main flue at exit of economisers or chimney base	0·80 in W.G.
Temperature of flue gases before economisers	598° F.
Temperature of flue gases after economisers	478° F.
Percentage of CO_2 in flue gases from side flue of boilers by means of combustion recorder	7·6 per cent.
Steam pressure :	
Pounds per square inch (gauge)	89
Pounds per square inch (absolute)	104
Temperature of saturation of steam	330·5° F.
Temperature of superheated steam	346·5° F.
Steam or power used as auxiliary to the production of steam	2·4 per cent.
Thermal efficiency :	
(A) Net working efficiency complete, after deducting 2·4 per cent. steam or power used as auxiliary to the production of steam	60·09 per cent.
(B) Boilers only	56·71 per cent.
(C) Economisers only	4·35 per cent.
(D) Superheaters only	0·51 per cent.

(B) *Long Check Test:*

(One week of 7 days.)

Duration	. 167·5 hours.
Price of fuel used	. 14*s*. 6*d*. per ton delivered.
Amount of fuel used	. 128·25 tons.
Water evaporated	. 184,435·0 galls.
Water evaporated per lb. of fuel	. 6·42 lb.

Also I gave in *Engineering*, July 25 and August 1, 1919 ('Exact Data on the Running of Steam Boiler Plants. No. 2.—The Performance of Colliery Steam Boiler Plants'), the separate figures for the tests of 100 different colliery boiler plants, representing 570 boilers with an annual coal bill of 1,250,000 tons. The average figures for these 100 tests are given on p. 413, along with 60 chemical works, 250 plants of all industries, and a modern plant run on the best lines of boiler house management for comparison. It may be noted that the colliery industry has the lowest efficiency (55·5 per cent.) of any.

I feel sure these tests represent the true average performance of boiler plants in Great Britain, because the 2,000 plants inspected, equivalent to a coal bill of about 15,000,000 tons per annum, are all running on the same general lines.

In my opinion, therefore, the average nett working efficiency of the steam boiler plants (boilers, economisers, and superheaters) of Great Britain, burning 90,000,000 tons of coal per annum, is only about 58 per cent., corresponding to, say, $6\frac{1}{2}$ lbs. of water per lb. coal, or $7\frac{1}{2}$ lbs. from and at 212° F. By the adoption of modern methods of boiler house management the nett working efficiency of boiler plants can be raised to 75 per cent. This is not a theoretical or impossible figure, but a reasonable and practical basis such as quite a number

—	60 Chemical Boiler Plants.	250 Boiler Plants typical of all Industries.	100 Colliery Boiler Plants.	Modern Plant run on Scientific Lines.
Duration of test	9·2 hours	9·43 hours	9·68 hours	6·75 hours
Type of boiler	Chiefly Lanc.	Chiefly Lanc.	Chiefly Lanc.	Lanc.
Number of boilers	Average 3·9	Average 4·0	Average 5·7	Average 4·0
Grate area	156·5 sq. ft.	152·6 sq. ft.	217·6 sq. ft.	130·0 sq. ft.
No. of tubes in economiser	Average 300	Average 200	Average 50	Average 576
Analysis of coal used:				
B.Th.U.	11,350	11,822	10,500	11,980
Ash	12%	11·5%	11·5%	12·5%
Amount of coal burnt	38,025 lbs.	30,131 lbs.	39,815 lbs.	28,200 lbs.
Coal burnt per boiler per hour	1,059·8 lbs.	798·8 lbs.	721·5 lbs.	1,044·4 lbs.
Coal burnt per sq. ft. grate area per hour	26·6 lbs.	20·9 lbs.	18·9 lbs.	32·1 lbs.
Draught:				
Chimney-base	0·70″ W.G.	0·80″ W.G.	0·95″ W.G.	1·75″ W.G.
Side-flues	0·38″ W.G.	0·40″ W.G.	0·60″ W.G.	0·70″ W.G.
Temp. of flue gases:				
Before economiser	—	598° F.	690° F.	620° F.
After economiser	—	478° F.	660° F.	310° F.
Percentage of CO_2	8·5%	7·6%	7·5%	12·0%
Total water evaporated	23,358 gals.	19,777 gals.	21,690 gals.	22,405 gals.
Water evaporated per boiler per hour	651 gals.	524 gals.	393 gals.	829 gals.
Temp. of feed-water:				
Before economiser	103° F.	116° F.	137° F.	95° F.
After economiser	215° F.	193° F.	154° F.	305° F.
% saving due to economisers	10·1%	7·1%	1·6%	18·5%
Steam Pressure. Gauge	102 lbs.	89 lbs.	86 lbs.	158 lbs.
Temperature of saturated steam	339·2° F.	330·5° F.	328·4° F.	370° F.
Temperature of superheated steam	384·2° F.	346·5° F.	350·0° F.	540° F.
Steam or power used as auxiliary to the production of steam	6·1%	2·4%	1·8%	3·5%
Lbs. water per lb. coal	6·1 lbs.	6·56 lbs.	5·44 lbs.	7·94 lbs.
Lbs. water from and at 212° F. per lb. coal	7·0 lbs.	7·46 lbs.	6·07 lbs.	9·21 lbs.
Lbs. water from and at 212° F. per 1,000,000 B.Th.U.	616·7 lbs.	631·0 lbs.	578·1 lbs.	768·7 lbs.
Efficiency:				
1. Nett working	57·9%	60·09%	55·52%	78·68%
2. Boilers only	54·2%	56·71%	55·02%	60·99%
3. Economisers only	0·1%	4·35%	0·90%	14·16%
4. Superheaters only	1·3%	0·51%	0·62%	6·39%

of firms have already obtained by the exercise of care and commonsense, and with ordinary and well-known plant, machinery, and appliances.

The difference between the present average figure of 58 per cent. efficiency and 75 per cent. represents a loss of 22 per cent. in the coal bill. That is to say, we are losing in Great Britain per annum the enormous amount of 20,000,000 tons of coal because of lack of proper methods of boiler house management. Also, since our civilisation depends largely on coal, it is painfully interesting to note that throughout the world such loss amounts to at least 100,000,000 tons per annum, Great Britain being probably no worse in this respect than any other country.

Considering now in order the sections of the paper specified by the Council:

1. Types of Boilers, With Their Relative Advantages and Disadvantages.

The tendency of boiler design, from the days of the very first small boilers used by Savery about 1698 to the present time, has been in the main to increase, first, the size and working pressure, and, secondly, the efficiency and output by improving the circulation of the water in the boiler.

The first large practical boiler, the externally fired cylindrical boiler, was invented in Cornwall about 1770 (probably by Richard Trevithick, senior), and still exists to-day in a few collieries, 150 years after its original invention, as the 'egg-ended' boiler. This boiler is more or less on the lines of the domestic kettle, and in addition to structural defects the circulation of the water is very bad. The same remarks also apply to the 'wagon' boiler, introduced about 1780 by James Watt, which has, however, long since gone out.

The real inventor of the modern steam boiler was the famous Richard Trevithick, who designed the ' Cornish ' boiler (the internally fired cylindrical boiler) about 1797, and the ' Lancashire ' boiler, first produced in 1841, was a minor development introduced by Fairburn. The ' Cornish ' and the ' Lancashire ' boilers have in practice quite a good circulation, are very efficient (combined with economisers and superheaters), will work at very high pressures (up to 200 lbs.), and the structural design is excellent, so that over 20 years is quite a common average life.

The ' water-tube ' boiler was invented to increase the speed of circulation of the water, and is in this respect a considerable advance on the ' Lancashire ' boiler.

To-day, from the point of amount of evaporation, probably about 85 per cent. of the boilers of Great Britain are of the ' Lancashire ' (or ' Cornish ') type, or adaptations of these, with, say, 10 per cent. of the ' water-tube ' type, in addition to a considerable number of ' vertical ' boilers and a few ' marine ' or ' egg-ended ' boilers, and the question of the advantages and disadvantages of types of boiler really resolves itself, therefore, into the ' Lancashire ' boiler *versus* the ' Water-tube ' boiler.

The essentials of the matter are that the water-tube boiler is more efficient but more complicated, that is, one has to choose between slightly better results at the expense of more anxiety and attention.

It is very difficult, however, to give a decisive opinion as to which is the best type of boiler, and, frankly, the more experience one gets the more difficult it is to answer definitely such conundrums. The advantages and disadvantages from a practical point of view may be tabulated as on pp. 416 and 417.

<table>
<tr><th>—</th><th>‘ Lancashire ’ Boiler.</th><th>‘ Water-tube ’ Boiler.</th></tr>
<tr><td>Circulation of water</td><td>Fairly good in practice.</td><td>Very good, and much better than the ‘ Lancashire ’ boiler.</td></tr>
<tr><td>Working pressure</td><td>Will work up to 200 lbs., although 180 lbs. is the best practical maximum.</td><td>Will work at much higher pressure, say up to 350 lbs.</td></tr>
<tr><td>Superheat</td><td colspan="2">No difference in this respect. Both boilers will work at 200° superheat or higher.</td></tr>
<tr><td>Economisers</td><td colspan="2">No difference, and cast-iron economisers can be used on both boilers up to 200 lbs. pressure.</td></tr>
<tr><td>Mechanical and hand stoking</td><td>Lends itself very well to hand stoking.

In general, mechanical stoking is less efficient because of the narrow grates and difficulty of ash disposal.</td><td>Cannot fire by hand (for ordinary 20,000 lbs. boiler and over).

In general, mechanical stoking is more efficient.</td></tr>
<tr><td rowspan="2">Floor space</td><td>Floor space, with auxiliaries (economiser, etc.), is considerable.</td><td>Floor space for equal evaporation is much less.</td></tr>
<tr><td colspan="2">This advantage of the ‘ water-tube ’ boiler is not of much practical importance, because the average industrial concern is not short of floor space.</td></tr>
<tr><td rowspan="2">Quickness of steam raising</td><td>The speed of steam raising is much slower.</td><td>The speed of steam raising is very fast, more than twice that of the ‘Lancashire’ boiler.</td></tr>
<tr><td colspan="2">This advantage also of the ‘ water-tube ’ boiler is not of much importance on land boiler plants.</td></tr>
<tr><td>Water reserve in the boiler</td><td>The water reserve is very great.</td><td>The water reserve is very small, and it is almost necessary to use automatic feed-water regulators.</td></tr>
</table>

<table>
<tr><th>—</th><th>‘ Lancashire ’ Boiler.</th><th>‘ Water-tube ’ Boiler.</th></tr>
<tr><td>Scale and bad feed-water</td><td>Moderate scale is of much less importance to the ‘ Lancashire ’ boiler, and has practically no bad effect on the boiler.</td><td>Moderate scale has the most serious results both for efficiency and wear and tear on the boiler.</td></tr>
<tr><td>Skilled attention .</td><td>Much less attention is required.</td><td>Much more skilled and careful attention is essential.</td></tr>
<tr><td>Cost of installation complete with all auxiliaries, economisers, superheaters, mechanical stokers, mechanical draught, brickwork and foundations, but exclusive of chimney</td><td>More expensive than water-tube boilers. For 40,000 lbs. evaporation would cost to-day roughly £28,000 (5 ‘ Lancashire ’ boilers, etc.).</td><td>Less expensive than ‘Lancashire’ boilers. For 40,000 lbs. evaporation would cost to-day roughly £22,000 (2 × 20,000 lbs. boilers).</td></tr>
<tr><td>Wear and tear, cost of upkeep, and liability to break down</td><td>Very little, and ‘ Lancashire’ boilers have been known to work even for fifty years, whilst over twenty years is quite common.</td><td>Unless with the most careful attention the cost of upkeep and wear and tear is considerable, and the liability to break down very great. Repair of tubes, caps, etc., is apt to be a particularly costly item.</td></tr>
<tr><td rowspan="2">Efficiency . . .</td><td>In general, slightly less.</td><td>In general, slightly greater, but not so much as is commonly supposed.</td></tr>
<tr><td colspan="2">Depends greatly on the design of the plant, the care and attention it receives, the methods of control adopted, the quality of the feed-water, the variation in the demand for steam, and other factors.</td></tr>
</table>

It is particularly difficult to give a general opinion as to the relative efficiencies of the 'Lancashire' and 'water-tube' boilers because of the almost universal lack of proper methods of boiler house management. I should say that, on an optimistic estimate, 5 per cent. of the boiler plants of the country receive the best and most up-to-date attention, 85 per cent. moderate and average, and 10 per cent. very bad indeed. On this assumption I gave the relative efficiencies of various types of boiler ('Exact Data on the Performance of Steam Boiler Plants. No. 4.—Average Figures for the Performance of some Different Types of Steam Boilers,' *Engineering*, December 10 and 17, 1921) as on p. 419.

The shocking efficiency (34 per cent.) of the 'egg-ended' boiler will be noted, ordinary 'vertical' boilers being about 48 per cent., and very small 'Lancashire or 'Cornish' boiler plants, generally of one boiler, such as are found in hotels, hydros, potteries, laundries, etc., are about 54 per cent. The average 'Lancashire' boiler plant (boilers, economisers, and superheaters) is working at about 60 per cent. efficiency, whilst the figures for the average 'water-tube' plant are, say, 69 per cent.

It will be obvious, therefore, that the suitability and advantages of 'Lancashire' and 'water-tube' boilers respectively are matters for the most careful consideration, and depend largely on the local conditions of the particular site and the methods of control to be adopted.

2. Mechanical Stoking.

In discussing mechanical stoking we have to remember that for 'water-tube' boilers (say 10 per cent. of boilers) mechanical stoking is essential because of the large size of the boilers, whereas for 'Lancashire' and other cylindrical boilers (85 per cent.) either hand or mechanical stoking can be adopted. I dealt at some length with mechanical stoking in a recent paper ('Exact Data on the Performance of Mechanical

—	('Lancashire,' &c.).			Water-tube Boiler.			Small Cylindrical Boiler Average.	Small Vertical Boiler Average.	Egg-ended Boiler Average.
	Average Plant, 85 per cent.	Good Plant, 5 per cent.	Bad Plant, 10 per cent.	Average Plant, 85 per cent.	Good Plant, 5 per cent.	Bad Plant, 10 per cent.			
Coal burnt per boiler per hour . . lb.	864·7	1,059·8	755·2	2,938·3	2,859·9	2,911·7	346·8	112·75	630·0
Coal burnt per sq. ft. grate area per hour lb.	22·7	27·9	19·8	20·9	20·4	20·8	17·3	—	22·5
Water evaporation per sq. ft. grate area per hour . . . . lb.	151·3	223·7	111·3	147·2	160·9	133·7	101·7	—	83·9
Water at 110° F. evaporated per lb. of coal .	6·65	8·02	5·62	7·01	7·87	6·43	5·86	5·25	3·73
Water from and at 212° F. evaporated per lb. of coal	7·62	9·28	6·42	8·12	9·11	7·46	6·71	6·01	4·26
Water from and at 212° F. per 1,000,000 British thermal units . . . . . . lb.	635·0	856·7	535·1	676·6	759·2	621·6	559·2	500·9	355·0
Temperature of inlet water . . . ° F.	110	110	110	110	110	110	110	110	110
Temperature of water after economisers ° F.	230	335	no ecn.	195	225	no ecn.	no ecn.	no ecn.	no ecn.
Saving due to economisers . . per cent.	11·0	20·4	nil	7·4	10·4	nil	nil	nil	nil
Draught in chimney base or fan inlet in W.G.	0·75	2·00	0·50	0·50	0·65	0·75	0·50	0·30	1·00
Temperature of gases leaving boiler . ° F.	600	650	500	475	450	575	590	800	850
Temperature of gases at chimney base or fan inlet . . . . ° F.	450	310	500	325	300	575	590	800	850
Analysis of feed-water—									
Permanent hardness . . . deg.	9	5	12	6	3	9	9	9	12
Temporary hardness . . . deg.	2	0	5	2	0	2	2	2	5
Percentage CO_2 in gases leaving the furnaces .	7·5	12·0	5·0	6·0	12·5	5·0	5·0	5·0	3·75
Average gauge pressure . . . lb.	75	159	60	155	160	150	70	70	55
Temperature of saturated steam . . ° F.	320·3	370·2	307·3	368·2	370·7	365·9	316·1	316·1	302·9
Temperature of superheated steam . . ° F.	nil	540	nil	530	650	450	450	nil	nil
Steam or power used auxiliary to the production of steam . . . . per cent.	2·5	2·5	5·0	2·0	1·5	2·5	nil	nil	nil
Efficiency—									
Net working . . . . per cent.	60·0	79·0	49·2	69·2	81·9	61·0	54·1	48·4	34·3
Boilers only . . . . per cent.	54·7	59·5	51·8	60·3	65·8	59·9	54·1	48·4	34·3
Economisers only . . . per cent.	6·8	15·3	nil	4·9	7·6	nil	nil	nil	nil
Superheaters only . . . per cent.	nil	6·2	nil	5·4	9·7	2·6	nil	nil	nil
Cost in coal to evaporate 1,000 gallons of water pence	332·6	266·9	380·8	305·3	272·0	333·2	365·2	408·1	574·4
Coal bill for 20,000,000 gallons evaporation, £	27·472	22,748	32,166	25,688	22,920	28,120	31,886	35,000	49,818

Stoking as Applied to "Lancashire" and other Narrow-flued Boilers') read on March 19, 1920, before the Institution of Mechanical Engineers. About thirty-five engineers took part in the discussion on this paper, and the differences of opinion expressed were very striking. From the point of view of boiler house management, the advantages and disadvantages of mechanical stoking as applied to 'Lancashire' or other cylindrical boilers can be expressed briefly as below :

(1) *Efficiency.*—The most fantastical claims are usually made with regard to the efficiency obtained with mechanical stokers. In the paper before the Institution of Mechanical Engineers already mentioned, I gave the detailed figures for the actual performance of 80 mechanically fired boiler plants in about 15 different industries, representing 299 'Lancashire' boilers, with a total coal bill of 715,000 tons per annum; 8 different makes of mechanical stoker were represented, 5 coking and 3 sprinkling.

The average nett working efficiency of these 80 plants, which can be taken as representative of the mechanically fired cylindrical boiler plants of the country, including economisers and superheaters, and deducting the steam or power used auxiliary to the production of steam, was 59 per cent., corresponding to 53 per cent. for the boilers only.

The efficiencies of the 80 plants were divided as in first table on p. 421.

I have figures in my possession relating to about 350 hand-fired plants, and the average nett working efficiency of these plants is about 61–62 per cent. That is to say, on these results, mechanical firing is actually giving inferior results to hand firing. There is, in my opinion, in practice little difference in efficiency on all the boiler plants of Great Britain between hand fired and mechanically fired plants, and if the methods of supervision and control of the plant are good or bad, the results with both hand and mechanical firing are also

equally good or bad. Mechanical firing in practice is giving anything from 40–80 per cent. efficiency, and the same applies to hand firing.

	80 Plants Mechanically Fired.		250 Plants (76 per cent. Hand Firing and 24 per cent. Mechanical Firing).	
	No. of Plants.	Per cent.	No. of Plants.	Per cent.
Over 80 per cent. . .	1	1·25	2	0·8
75–80 per cent. . .	2	2·50	9	3·6
70–75 ,, . .	2	2·50	13	5·2
65–70 ,, . .	17	21·25	30	12·0
60–65 ,, . .	11	13·75	44	17·6
55–60 ,, . .	16	20·00	62	24·8
50–55 ,, . .	15	18·75	47	18·8
Less than 50 per cent. .	16	20·00	43	17·2
	80	100·00	250	100·0

The 80 plants gave a slightly better figure (average 8·25 per cent.) for CO_2, 350 plants hand fired being about 7·5 per cent., and the CO_2 figures can be detailed as follows :

	80 Plants Mechanically Fired.		250 Plants, typical of the Whole Country (76 per cent. Hand Fired and 24 per cent. Mechanically Fired.	
	No. of Plants.	Nearest per cent.	No. of Plants.	Nearest per cent.
Very good, over 12 per cent.	3	4	4	1·6
Good, 10–12 per cent. .	12	15	17	6·8
Medium, 8–10 per cent. .	24	30	64	25·6
Poor, 5–8 per cent. . .	35	45	144	57·6
Very bad, under 5 per cent.	5	6	21	8·4
Total . .	79*	100	250	100·0

* One plant CO_2 not determined.

(2) *Life of the Boiler.*—It is often claimed that mechanical stoking is better for the boiler, because there is no contraction and expansion due to cold air being admitted when the fire doors are opened, as with hand firing. This is academically correct, but it is of no practical importance, as hand fired boilers have been known to last fifty years. On the other hand, mechanical stokers, because of lack of proper supervision, have often seriously increased the wear and tear on the boiler.

(3) *Amount of Steam Produced.*—Another claim is that mechanical stoking increases the steam output of the boiler, and the Coal Control Board, for example, spread this statement broadcast. My opinion is that in averages there is little or no difference between hand and mechanical firing in this respect. The average figure for the 80 mechanically fired plants was 6,000 lbs. evaporation per hour for 'Lancashire' boilers $30' 0'' \times 8' 0''$, a figure identical with that of 350 hand fired plants.

(4) *Flexibility of Steam Output.*—It is a defect of mechanical stoking that it will not respond to sudden and erratic demands for steam as well as hand firing.

(5) *Flexibility in Quality of Fuel Used.*—It is also a defect of mechanical firing that it reduces the 'flexibility' of the plant from the point of view of the coal burnt. Thus, the installation of sprinkling stokers at once restricts the steam user to coal that will 'sprinkle,' just as a coking stoker means that only coking coal can be used. It is true that mechanical stokers will burn certain kinds of refuse coals more efficiently than hand firing, but on the other hand many qualities of refuse coal can only be burnt by hand firing.

For the best results with mechanical firing, a definite and uniform quality of coal is necessary, so that the most suitable stoker can be chosen for these restricted conditions. It is this lack of flexibility that makes the application of mechanical

stoking to colliery boiler plants so difficult, because, as is well known, all kinds of fuel are apt to be thrown into the colliery firehole, and for this reason hundreds of mechanical stokers have been scrapped at collieries. Also the conditions of the average colliery boiler plant, working in the open air with little attention, are particularly trying for mechanical stokers. In spite of these obvious facts, the amazing Coal Control Board recommended mechanical stoking for collieries.

(6) *Amount of Fuel Burnt.*—In averages, mechanical stokers are burning slightly more per boiler than hand firing, but there is little difference.

(7) *Black Smoke.*—Mechanical stoking is, in averages, undoubtedly superior to hand firing for the prevention of black smoke, and in fact mechanical stoking was originally invented for the sole object of preventing black smoke.

The figures for the 80 plants in comparison with 250 plants (76 per cent. hand fired) are as follows :

Black Smoke	80 Plants Mechanically Fired.		250 Plants (76 per cent. Hand Fired and 24 per cent. Mechanically Fired).	
	No. of Plants.	Per cent.	No. of Plants.	Per cent.
Good	23	28·75	65	26·0
Fairly good . . .	31	38·75	62	24·8
Medium . . .	24	30·00	75	30·0
Bad	2	2·50	43	17·2
Chronic	0	0·00	5	2·0
	80	100·00	250	100·0

(8) *Cost of Upkeep.*—The first practical mechanical stoker in the history of the world was invented by William Brunton in 1819, and the first installation supplied was in 1820 to the

works of Messrs. Liptrap & Smith, a firm of distillers in Whitechapel, London. Although this first mechanical stoker was in general satisfactory, when it had been running some time the two chief disadvantages were found to be that it would not answer to the fluctuating steam demands of the distillery so well as hand firing, and that the cost of upkeep was very high. To-day, over 100 years after, these are still two of the inherent defects of mechanical stoking. There is bound to be considerable upkeep when the moving parts of a machine are in contact with a red-hot furnace. An average figure to-day for the cost of upkeep is probably about £40 per boiler per annum above hand firing for the life of the mechanical stoker, but with good boiler house management this could be reduced by about half.

(9) *Steam Jets.*—A serious defect of mechanical stoking, as usually worked to-day, is the amount of steam used by steam jets, and the average figure for the 80 plants was 6·6 per cent. of the production of the boiler plant, individual plants varying from nil to $21\frac{1}{2}$ per cent. of the production. 6·6 per cent. of the production—that is, 6·6 per cent. of the coal bill—is equivalent to the cost of a complete new mechanical stoker, say, every 12 months, and many large plants are squandering 1,000–5,000 tons of coal per annum on steam jets alone.

The figures of the consumption of the steam production can be divided as in table, p. 425, and further data is given later under the item of forced draught, p. 433.

(10) *Cost of Labour.*—Mechanical stoking, as a general rule, only saves labour when the plant is over four 'Lancashire' boilers, and even on a comparatively large plant the saving is not very much. On large plants, which are, however, rare, the saving is considerable.

(11) *Skilled Attention.*—More skilled attention is required

by mechanical stoking, although this is not really a disadvantage.

(12) *Better Conditions in the Firehole.*—It is a very great advantage of mechanical stoking that the laborious work of throwing on coal, and above all of cleaning out, is practically eliminated. Also, mechanical stoking lends itself very well to mechanical coal and ash handling plant. In view of the attitude of labour, these are practical points of the greatest importance.

(13) *Capital Outlay, Interest, and Depreciation.*—This is, of

—	No. of Plants.	Per cent.
0–2½ per cent. of production . .	9	11·25
2½–5 ,, ,, . .	33	41·25
5–7½ ,, ,, . .	17	21·25
7½–10 ,, ,, . .	11	13·75
Over 10 ,, ,, . .	10	12·50
	80	100·00

course, an inherent defect in mechanical stoking. Interest at 6 per cent. on the outlay and 12 years' life will swallow up 2–3 per cent. saving on the coal bill. As with the 'Lancashire' *versus* 'water-tube' boiler question, it is very difficult to say whether mechanical stoking is an advantage or otherwise in competition with hand firing on 'Lancashire' and other cylindrical boilers. There is nothing to beat good hand firing, but the difficulty is to find it.

Under present average conditions I should say, finally, that mechanical firing has the advantage, provided—and this is the crux of the whole matter—the right type of mechanical stoker is chosen and it receives continual care and attention just like any other machine, and also that the whole plant is controlled by proper methods of boiler plant management.

3. Economisers and Feed-Water Heaters.

With regard to economisers, these are, of course, absolutely essential to the most efficient results on practically every boiler plant. The advantages are well known to every one, and include a great saving in the coal bill by utilising the waste heat of the boiler flue gases, the reduction of the strain on the boilers by the provision of a high temperature feed-water, the increased evaporative capacity of the boiler, and the provision of a large reserve (say 1–1½ hours' supply) of hot feed-water.

As regards the saving obtained, the makers of economisers now state this to be 15–20 per cent. (not 15–25 per cent. as a short time ago) of the coal bill; but this is correct only if the economiser is installed on right lines and the plant worked correctly.

In the tests on 250 plants already mentioned, the results of the economisers can be tabulated as on p. 427.

That is to say, in practice, out of 250 plants 95 plants had no economisers at all, and wasted, say, in averages 17½ per cent. of the coal bill. The 155 plants fitted had an average saving of 11½ per cent. of the coal bill, corresponding to 7·6 per cent. for the whole 250 plants. Only 24 boiler plants out of the 155 plants fitted with economisers were saving 15 per cent. or over of the coal bill, and only 8 plants were saving 17½ per cent. or over.

The general reason for these low results is that the lay-out of the economiser plant is faulty and not enough tubes are installed, whilst also the installation is defective through lack of attention. An average figure of 7½ per cent. saving in the coal bill, instead of 17½ per cent., means a loss of 10 per cent., that is 9,000,000 tons per annum in Great Britain through lack of proper economiser installation alone. In

Table Showing Results of Working with Economisers.

Division according to Saving obtained.	No. of Plants.	Average Temp. of Feed-water.		Average Temp. of Flue-gases.		Draught in Inches. W. G.		Steam Press. Gauge.	Total Evaporation on Plant per Hour.	No. of Tubes on Plant.
		Before.	After.	Before.	After.	Chimney Base or	Side Flue Downtake of Blowers.			
		° F.	° F.	° F.	° F.				Lbs.	
No economiser at all .	95	..	..	..	..	..	..	..	..	..
Less than 5 per cent. .	14	134	172	568	371	0·85	0·41	80	17,616·0	228
5 to $7\frac{1}{2}$ per cent. . .	15	123	194	576	423	0·61	0·35	79	15,340·0	203
$7\frac{1}{2}$ to 10 per cent. . .	23	119	261	549	374	0·74	0·33	100	16,630·0	231
10 to $12\frac{1}{2}$ per cent. . .	33	118	243	583	403	0·88	0·39	106	29,723·0	401
$12\frac{1}{2}$ to 15 per cent. . .	46	110	262	584	379	0·99	0·41	99	19,760·0	280
Over 15 per cent. . .	24	170	284	610	375	1·35	0·60	119	23,497·0	392
Total plants .	250									

most cases economisers are installed on purely 'rule-of-thumb' lines alone, such as 72, 96, or 144 tubes per 'Lancashire' boiler, irrespective of the evaporation of the boiler, which may be anything from 300 to 1,000 gallons per hour.

The disadvantages of the economiser are that it reduces the natural draught of the chimney, because the temperature of the flue-gas is lowered, encrustation inside the tubes from scale, corrosion of the pipes, and of course the interest on the capital outlay and the depreciation. In general, the life of the economiser averages only ten years, and through especially faulty attention many economisers only last five years.

An economiser installation on proper lines has the inlet water not less than 100° F., so as to stop corrosion due to 'sweating' (either by means of a circulator or heating the feed-water), and after passing through the economiser the feed-water will average about 300° F., corresponding to, say, 18 per cent. saving in the coal bill. The flue-gases leaving the boiler will average 625° to 675° F. and be cooled by the economiser to 300° to 325° F. before discharging to the chimney.

The water should not exceed 6° to 7° total hardness, these results being obtained by the installation of a softening plant if necessary, and the bottom boxes of the economiser should be above the ground level to avoid damp flues. The drive gearing, etc., must be kept in perfect condition, so that the scrapers never stop whilst the hot gases are passing. Such an installation will last twenty years without any difficulty and represent a handsome investment on the money.

The prejudice that still exists to-day in the colliery industry against economisers is very curious, although it is over seventy years since the economiser was invented by Edward Green. Out of the 100 colliery boiler plants tested, only 19 plants were equipped with any economiser at all, and 11 of

these plants had a saving of less than 10 per cent. of the coal bill. It is presumably a persistent relic of the days when coal was of little value, and when water-softening plants were to some extent imperfect, so that the notoriously bad water of most collieries was passed direct into the economiser, and the tubes became choked with scale in a few months. The obvious remedy is to soften the water, and not waste $17\frac{1}{2}$ per cent. of the coal bill by scrapping the economiser.

The feed-water heater is also a valuable adjunct to the boiler plant, but is very little used. All the exhaust steam available, such as the boiler-feed pumps, small economiser engine, mechanical stoker engine, mechanical draught engine, etc., should be usefully employed in a feed-water heater, so as to heat the inlet water on the way to the economiser. In this way a rise of 50° or 60° F. in the feed-water, say 4–5 per cent. saving in the coal bill, is easily obtained, and the capital outlay on the feed-heater is comparatively trifling.

4. Superheaters.

The value of superheating is also not realised. In the 250 plants only 80 plants were fitted with any superheaters at all, and of these only 25 plants were completely equipped, and these figures are probably about representative of all the boiler plants of the country.

Superheating can be applied in two ways—first as partial superheat to, say, 75° F., and secondly, full superheat from 120°–200° F. Partial superheat is of great value in thoroughly drying the steam and preventing condensation losses, especially in the long and exposed steam-pipe ranges of the average colliery. In the first place, steam as it comes from the boiler contains anything from 0·5–5 per cent. moisture, apart from

priming, and the superheater converts this moisture into useful steam. If there is then, say, 75° F. or other suitable superheat temperature in the steam leaving the superheater, this heat will be gradually lost in traversing the steam-pipe circuits, but there will be no condensation, and dry steam with little or no superheat will result at the end of the circuit.

High superheat is also a great aid to efficiency in steam engines or turbines, but can only be used in prime movers built for the purpose, because of lubrication troubles.

It will be no exaggeration to say Great Britain is losing at least 4,000,000 tons of coal per annum through lack of superheaters.

5. Forced or Induced Draught.

The term 'forced draught' is used in two senses—the correct one of mechanical forced draught with a fan, analogous to mechanical induced draught with a fan, and also as meaning the use of steam jets or blowers.

Taking mechanical draught first, forced and induced, there is no doubt that in general chimney draught is antiquated and inefficient. The draught in a chimney depends entirely, other things being equal, on the temperature. The higher the temperature of the exit flue gases in the base, and the greater the waste of coal, the better the draught. As soon as economisers are put in to stop this waste and save $17\frac{1}{2}$ per cent. of the coal bill by reducing the gases from 650° to 325° F., the draught is choked.

With mechanical draught the amount of draught has nothing to do with the temperature of the exit gases, and theoretically enough economisers could be put in to reduce the exit gases to, say, 212° F. without interfering with the working of the plant.

The advantages and disadvantages can be tabulated as follows :

Advantages.

(*a*) Enables the full heat to be extracted from the flue gases without interfering with the draught.

(*b*) Can work with very thick and white-hot fires, since any required draught can be obtained, and consequently high CO_2 with no CO results when proper methods of boiler house management are adopted.

(*c*) The draught is independent of climatic conditions, and is under perfect control, so that it can be altered at will according to the quality of the coal and the demand for steam.

(*d*) In the case of a new plant mechanical draught with a short steel chimney, all that is necessary, represents much less capital outlay than a large chimney.

(*e*) Enables refuse and cheap fuels to be burnt, which would be impossible with ordinary chimney draught, and induced draught is particularly valuable for collieries on this account.

Disadvantages.

(*a*) Takes 2–2½ per cent. of the steam production of the plant to work the fan, which must therefore be deducted in calculating the nett saving.

(*b*) The installation is a machine, and is therefore liable to break down if not given proper attention.

(*c*) Mechanical draught requires more skilled attention, and, for example, losses can occur by using excessive draught with thin fires at the back.

In comparing forced with induced draught almost equally

good results can be obtained, but forced draught has the slight objection that the blast has to be shut off (mechanically) every time the fire doors are opened, and a fairly high chimney is still necessary to take the gases away from the fires. A combination of induced and forced draught, known as balanced draught, is sometimes installed. For land practice induced draught is almost entirely used, and a large number of boiler plants have been equipped in Great Britain. In the 250 tests 32 were fitted with induced draught and 2 with mechanical draught, whilst 93 had steam jet furnaces (hand or mechanically fired), and the remaining 123 were working on chimney draught. In my opinion, in average cases some form of mechanical draught is essential to the best results, but proper methods of control must be adopted. In general, the mechanical draught steam plants of Great Britain are not obtaining any more efficient results than the chimney draught plants, but this is not the fault of mechanical draught and is due to the lack of boiler house management. In a large number of cases the fan installed is too small, and has no reserve of power, which is a fatal mistake. This is to make a cheap job, either because the steam user will not pay for a proper plant, or one of the lesser fan firms has persuaded the steam user that his quotation is cheaper without stating that the plant is smaller. Expressed in a few words, mechanical draught is more efficient and more complicated, as with many other boiler plant accessories.

Chimney draught can, however, be used very successfully if fairly good quality coal is used and the chimney is high enough to give, say, 1 in. suction water gauge in the base with flue gases at 325° F.

As regards jet furnaces a very large number of these appliances are in use, and probably over 30 per cent. of the boiler

plants of Great Britain are fitted with them. They have the advantage of being comparatively cheap to install, and require little or no attention to work. The big objection is the amount of steam used by the jets. In *Engineering*, January 16, 1919 ('Exact Data on the Running of Steam Boiler Plants. No. 3.—The Amount of Steam Used by Steam Jets'), I gave

Average Results for Hand Firing.

Averages 6·6 *per cent. of the production.*

Type of Apparatus.	No. of Plants.	No. of Boilers.	Percentage of Production.	Total Coal Bill.	Total Coal Bill used by Jets.
				Tons per annum.	Tons per annum.
Type A . .	6	17	7·6	20,200	1,535·2
Type B . .	4	7	4·5	15,400	693·0
Type C . .	3	6	7·3	9,234	674·0
Type D . .	18	60	6·3	137,005	8,631·5
Type E . .	7	22	8·1	55,450	4,491·4
Type F . .	2	3	3·2	5,850	187·2
Type G . .	2	4	5·0	6,600	330·0
Type H . .	2	6	7·7	14,400	1,108·8
Type I . .	3	6	4·4	8,525	375·1
Type J . .	1	2	15·25	4,000	610·0
Type K . .	6	16	5·9	35,346	2,079·5
	54	149		312,010	20,715·7

the data for the steam used by 11 different types of hand-fired steam jet furnaces, and 8 different types of mechanically fired furnaces on 130 boiler plants, with a coal bill of 1,000,000 tons per annum. The figures are as above and on p. 434, and both hand and mechanical steam jet furnaces are in averages taking the same amount of steam—namely, 6·6 per cent. of the production of the plant.

This amount of steam can, however, be cut down to about $3\frac{1}{2}$–4 per cent. if the jets are carefully watched, and especially if a steam meter be installed on main supply pipe feeding all the jets. Another minor objection is that the flue gases are apt to become very wet and tend to cause corrosion, especially on the economisers. Steam jet furnaces give very good results with certain classes of fuel, especially coke, coke-breeze, and small refuse coals, and they also have the advantage that the bars do not burn out, as the steam keeps them cool.

Average Results for Mechanical Firing.

Averages 6·7 *per cent. of the production.*

Type of Apparatus.	No. of Plants.	No. of Boilers.	Percentage of Production.	Total Coal Bill.	Total Coal Bill used by Jets.
				Tons per annum.	Tons per annum.
Type A—Sprinkling	25	73	5·00	140,345	7,017·2
Type B—Sprinkling	16	45	5·25	95,550	5,016·4
Type C—Sprinkling	7	23	5·00	30,070	1,503·5
Type A—Coking .	4	12	2·30	21,050	484·1
Type B—Coking .	1	3	13·80	5,750	793·5
Type C—Coking .	13	66	8·00	221,950	17,756·0
Type D—Coking .	1	3	7·20	4,900	352·8
Type E—Coking .	9	63	7·50	185,250	13,893·7
	76	288		704,865	46,817·2

6. Auxiliary Machinery.

As regards coal and ash conveyors, these are essential to a plant of any size, especially in conjunction with mechanical firing. It is not possible in a paper of this length to discuss conveyors in detail, but the chief point is to keep

them in thoroughly good condition to reduce the wear and tear.

The modern direct-acting feed pump of the 'Weir' type is a highly efficient machine, but, as already stated, it can be made still more efficient by using the exhaust in conjunction with a feed heater. For very large plants, say 40,000–50,000 gallons per hour evaporation and over, the modern practice is a turbine feed pump, in which all the steam used by the turbine goes back direct into the feed-water.

Another matter of importance is that of boiler and pipe covering, and in averages certainly 5–7½ per cent. of the national coal bill is lost because of condensation losses, apart from the question of partial superheating already discussed. Much pipe covering in use is of the most inferior quality, and collieries especially are very partial to cheap and shoddy coverings, in spite of the fact that their steam pipe ranges are almost the longest and most exposed of all industries. Only high-class coverings—magnesia, slag wool, or diatomite, with a high percentage of asbestos—should be used, and they are far the cheapest in the end. Also all flanges should be covered.

The feed-water should not go into the boiler plant over 10° in hardness, and, as already stated, with water harder than this a softening plant should be installed and the hardness brought down to 5–6°. There is also much prejudice in collieries against water softening plants, but even very bad colliery water, variable in quality, can be brought down to less than 10° total hardness.

The most important so-called 'auxiliaries' of a boiler plant, and they are just as essential as the plant itself, are the instruments necessary to maintain a proper control of the working of the plant. In fact, efficient boiler house management is far more a question of such control than of design

and equipment, and the lack of this control is one of the chief reasons why we are losing 20,000,000 tons of coal per annum on boiler plants. I do not think it would be an exaggeration to say that if proper control was carried out everywhere the national saving would be 5–8,000,000 tons per annum, and the remaining 12–15,000,000 tons to be saved would be due to bringing the plant, design, and equipment up to date.

A boiler plant must be regarded as a factory, in which is carried out a complicated series of operations, and whose output is steam at a given temperature and pressure, and a proper system of control or costing is just as necessary for these operations as it is for coal mining, the mass production of motor-cars or sewing-machines, or in fact any other technical operation.

The first essential is the installation of a water meter, and some method of checking the weight of the coal (in large plants by means of automatic coal-weighing machines), so that a continuous weekly record of the amount of water evaporated to steam and the amount of coal burnt is taken. There are over twenty different makes of water meter on the market, so there is ample choice.

Another vital matter for moderate-sized plants is the measurement of the amount of steam used at various main points on the plant, and for this purpose there are seven different steam meters available. Then the coal should be analysed regularly, so that the efficiency of the plant can be worked out, and combustion recorders must be installed to check the efficiency of the firing. About ten CO_2 recorders are on the British market, and the new 'Duplex Mono' recorder not only gives a continuous record of the percentage of CO_2, but also of CO and unburnt gas as well. Other items for a

large plant are draught gauges, pyrometers, recording steam gauges, etc.

Such methods are at present almost entirely unknown in Great Britain, and I should like to guarantee that 95 per cent. of steam plants have no efficient water meters, 99 per cent. no steam meters, 90 per cent. no CO_2 recorders, and 95 per cent. keep no proper performance log.

The remedy is obvious, and if we do not take it we shall go on wasting millions of tons of coal per annum and lose trade because our cost of production is too high. Most engineers have an idea that such methods are expensive. This is quite erroneous, as for a medium-sized plant of six 'Lancashire' boilers, burning 12,000 tons of coal per annum, there can be purchased a complete scientific outfit of instruments for about £1,000, and the skilled attendant necessary would cost, say, £350 per annum, a total annual cost of £600, including interest and depreciation. The saving on a conservative estimate would be 10 per cent. of the coal bill, that is 1,200 tons per annum, worth, say, £2,000, or £1,400 nett. We have proved this many times, and the facts are glaringly evident.

For even the smallest plant of one boiler a water meter costs less than £50, and the checking of the coal used nothing, and even these simple methods will generally save nearly 10 per cent. of the coal bill on such plants. In most steam plants, and especially in collieries, it is almost impossible to convince the management that it is a strict business policy to pay a man £7 or £8 a week to do nothing but look after the firehole, where, say, £20,000 a year is being spent and £4,000 a year simply wasted.

To sum up, boiler house management, whilst complicated, is really only the application of care and commonsense, and the money to be saved by its adoption is so great that it often

corresponds to several per cent. on the dividend of the Company. In any case we cannot go on squandering coal for ever, and we have got to remember that whilst Great Britain is at present no worse than the average, the first industrial country in the world that does adopt scientific methods of steam generation will have an enormous advantage in the struggle for trade.

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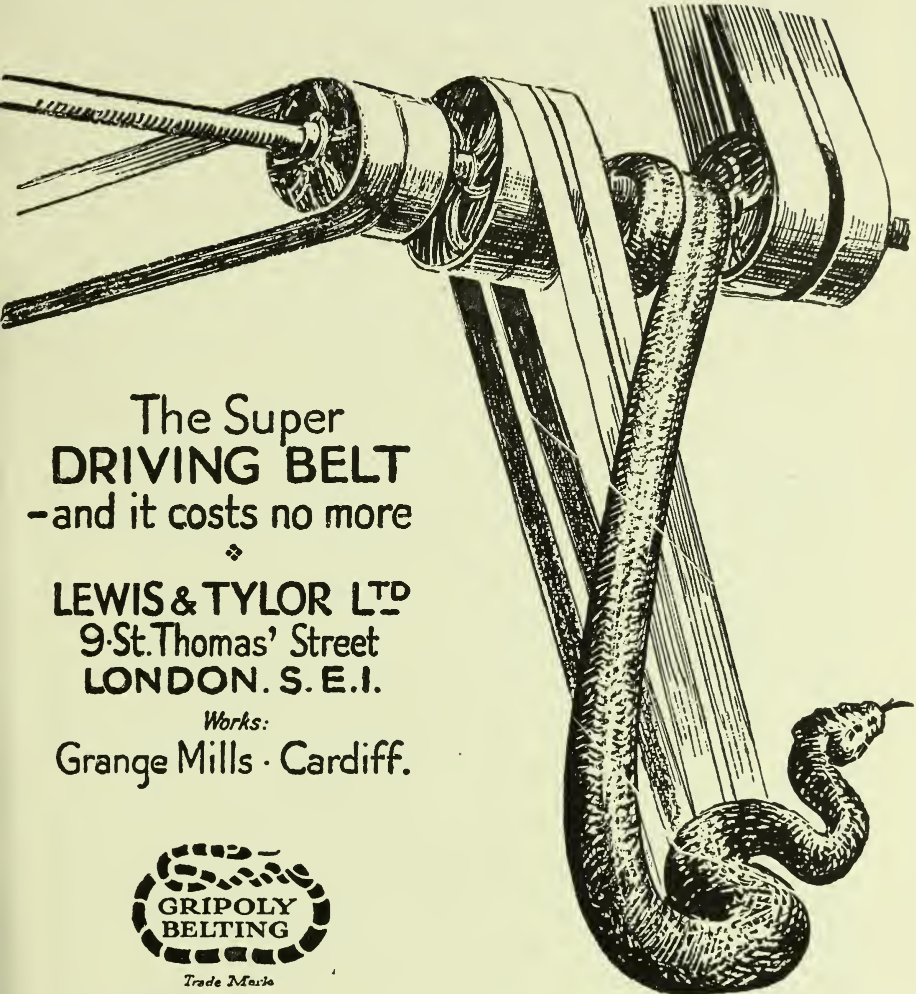

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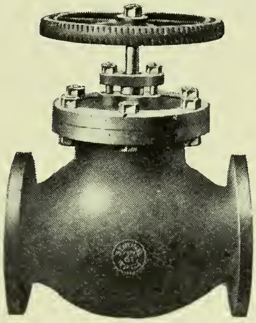

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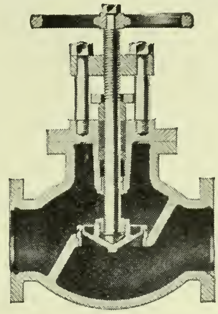

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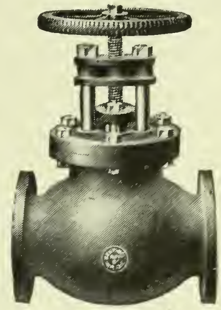

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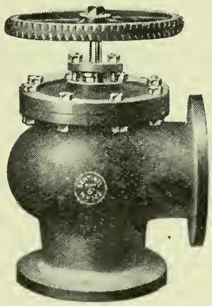

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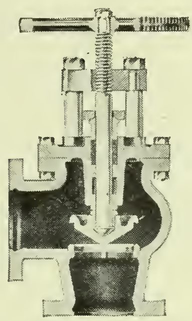

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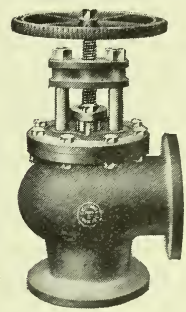

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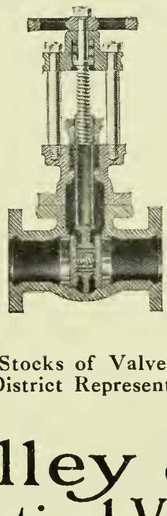

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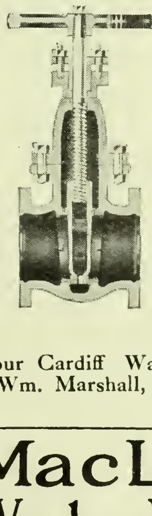

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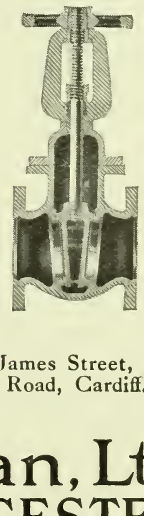

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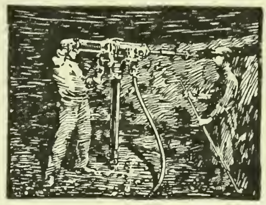

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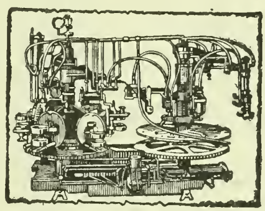

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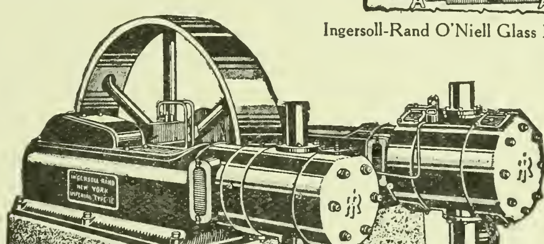

Here are the figure
Test at a South

REPORT ON THE TRIAL OF LANCASHIRE BOILER 9 FT. BY 30 FT. INSTALLED AT THE CAMBRIAN COLLIERIES LTD., CLYDACH VALE. THE BOILER WAS FITTED WITH A **BENNIS** SPRINKLER STOKER AND SELF CLEANING COMPRESSED AIR FURNACE (SOUTH WALES TYPE), AND THE TEST WAS COMPARATIVE BETWEEN **MACHINE STOKING** AND **HANDFIRING.**

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		SYSTEM OF FIRING	
		HAND	BENNIS MACHINE STOKER
DURATION OF TEST.	HOURS	24.	24.
GRATE AREA.	SQ. FT.	44.	46.
DRAFT.		NATURAL	NATURAL
DRAFT OVER FIRES.	INCHES.	·3.	·3.
DRAFT LEAVING BOILER.	,,	·6.	·6.
CO_2 IN GASES LEAVING BOILER.	%	11·15.	12·31.
TEMP. OF FEED WATER ENTERING BOILER.	DEGS. F.	190·8.	191·84.
STEAM PRESSURE BY GAUGE.	LBS. PER □"	136·4.	144·7.
NUMBER OF DEGREES SUPERHEAT.	DEGS. F.	120·23.	139·08.
FACTOR OF EVAPORATION INCLUDING SUPERHEATER.		1·1348.	1·1453.
NAME OF COAL.		CAMBRIAN SMALL.	CAMBRIAN SMALL.
COAL BURNT PER BOILER PER HOUR.	LBS.	982·3.	1446·7.
COAL BURNT PER SQ. FT. OF GRATE AREA PER HOUR.	LBS.	22·33.	31·45.
WATER EVAPORATED PER BOILER PER HOUR. ACTUAL.	LBS.	5554.	10390.
DITTO. AS FROM AND AT 212°.	LBS.	6303.	11900.
WATER EVAPORATED PER LB OF COAL. ACTUAL.	LBS.	5·65.	7·18.
DITTO. AS FROM AND AT 212°.	LBS.	6·42.	8·23.
THERMAL EFFICIENCY OBTAINED:— BOILER AND SUPERHEATER.	%	53·5.	66·77.
EXTRA WATER EVAPORATED, AS FROM AND AT 212° PER BOILER PER HOUR.	%		88·81.
EXTRA WATER EVAPORATED, AS FROM AND AT 212°, PER LB. OF COAL.	%		28·21.
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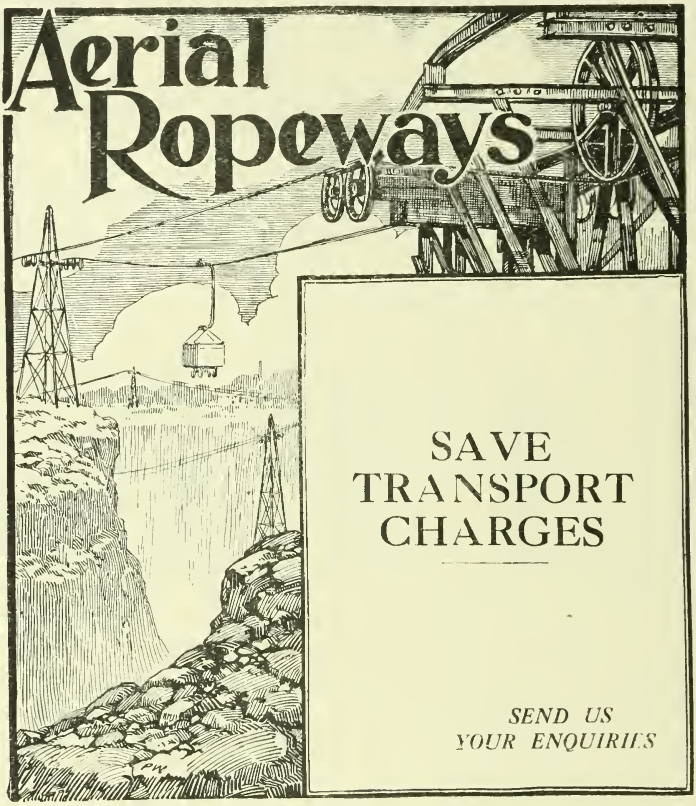

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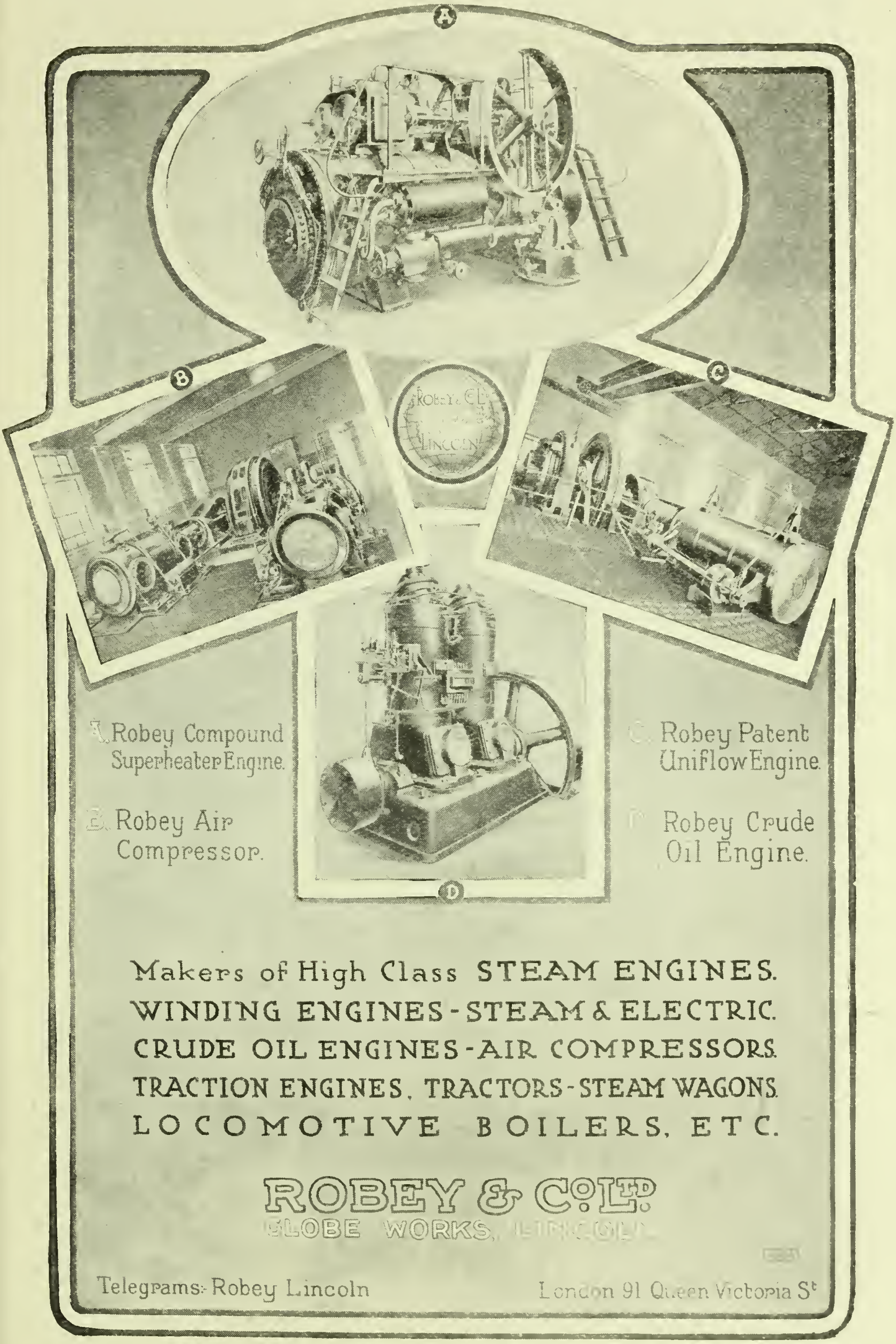

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Founded in 1895 by the late LORD MERTHYR of SENGHENYDD (Past-President), K.C.V.O., M.Inst.C.E., for the best Papers on subjects connected with Practical Mining and Practical Engineering, including Metallurgy.

1898. A First Prize was awarded to Mr. E. H. Thomas for his Paper on "Haulage," and a Second Prize to Mr. G. E. J. McMurtrie for his Paper on "Sinking."

1900. A First Prize was awarded to Mr. S. A. Everett, and a Second Prize to Mr. E. H. Thomas, for Papers on "Colliery Surface Arrangements."

1901. A Second Prize was awarded to Mr. Ralph Hawtrey, a Student, for his Paper "The Best and Most Economical System of Working Seams of Coal of Moderate Inclination in South Wales."

1904. A First Prize was awarded to Mr. H. D. B. How, A.M.I.E.E., for his Paper "Coal Winding Machinery."

1905. A First Prize was awarded to Mr. W. Waplington for his Paper "Description and Design of the Best Arrangements of Equipment of the Bottom, with a Radius of 400 yards, of a Pair of Pits to be Upcast and Downcast Respectively."

1906. A Second Prize was awarded to Mr. George Roblings for his Paper "Separation (Sizing) and Washing of Coal."

1907. A First Prize was awarded to Mr. Daniel Davies, and a Second Prize to Mr. Gath J. Fisher, for their Papers on "Pumping and Drainage," and also on "Sinking Shafts."

1908. A First Prize was awarded to Mr. H. A. Staples, a Second Prize to Mr. George Roblings, and a Third Special Prize to Mr. M. D. Williams, for their Papers "As to the Best Methods of Working Seams of Coal in Steep Measures."

1909. A First Prize was awarded to Mr. William Trimmer, and a Second Prize to Mr. C. W. Jordan, A.M.I.Mech.E., for their Papers on "General Lay-out and Equipment of a Complete Set of Engineering Shops for a Modern Colliery with an Output of about 2,000 tons per day."

1910. A First Prize was awarded to Mr. George Roblings, and a Second Prize to Mr. Noah T. Williams, for their Papers on "Washing and Sorting of Small Coal."

1913. Special Prize awarded Mr. Will Gregson for his Paper "The Most Approved Methods of Hauling the Coal from the Working Faces to the Pit Bottom."

1914. Special Prizes awarded Messrs. J. Williams and S. R. Cound for their Papers on "How to Improve Welsh Tinplate Rolling-mill Practice."

1918. A First Prize was awarded to Mr. W. T. Lane, and a Second to Mr. W. H. Casmey, for their Papers on "Fuel Economy in Power Production (or Utilisation of Waste Heat)."

1920. A First Prize was awarded to Mr. R. C. Morgan for his Paper on "Causes of Subsidences and the best Safeguards for their Prevention."

1921. Subject selected: "Improved Mechanical Methods for bringing Coal from long distances in view of the necessity for Increased Output." 1st Prize £20, 2nd £10.

INSTITUTE SCHOLARSHIP IN ENGINEERING.

Granted by the Council in 1904, and tenable for three years at the University College of South Wales and Monmouthshire.

1904.—An EXHIBITION of £60, awarded to Mr. Ernest Clarke Stroud, Chatham.

1905-08.—A SCHOLARSHIP of £70 per annum, awarded to Mr. E. C. Stroud.

1908-11.—A SCHOLARSHIP of £70 per annum, awarded to Mr. Ivor Richard Cox, Cardiff.

1912.—An EXHIBITION of £60, awarded to Mr. Victor John French, Chatham.

1912-15.—A SCHOLARSHIP of £70 per annum, awarded to Mr. Victor John French.

1915-18.—A SCHOLARSHIP of £70 per annum, awarded to Mr. E. W. H. Knight, Devonport,

NOTE.—Mr. Knight was unable to take up the Scholarship he had won, and an honorarium of £10 was granted him by the Council, also a Certificate to the effect that he had won the Scholarship.

1919-12.—An EXHIBITION of £13 (plus a bonus of £15) per annum, awarded to Mr. E. G. Davies, Cardiff. (Won in 1915.)

1919-21.—A SCHOLARSHIP of £70 per annum, plus a bonus of £15 per annum, awarded to Mr. Myrddin David, County School, Porth, and

1919-20.—An EXHIBITION of £30 per annum for two years, awarded to Mr. J. Selwyn Caswell, EbbwVale.

NOTICES.

The Editor of these Proceedings is directed to make it known that the Authors alone are responsible for the facts and opinions contained in their respective Papers, and the individual speakers for their statements made in discussion.

He is also directed to state that the COPYRIGHT of all the Papers and Discussions published in these Proceedings is the exclusive property of the Institute, and reproduction of any of the Papers is prohibited unless in each case the consent of the Council has been previously obtained.

PROCEEDINGS.

Back Numbers of the Proceedings have now been bound, from Vol. I. inclusive, in Volumes, in strong Duro-Flexile Cloth, and may be obtained from the Secretary at £1. 1*s*. per volume, or separate back numbers can be had at the various prices marked on the covers.

CHANGE OF RESIDENCE.

The Secretary would be obliged by Members notifying to him any alteration in their addresses at the earliest date.

INSTITUTE BUILDING.

The Institute, Park Place, Cardiff, is open for the use of Members on Week-days from 10 a.m. to 5 p.m.

The New Library is now open for the use of Members, and the technical journals and other periodicals will be found on the tables in that room, instead of in the Council Chamber.

SPENCE THOMAS SCHOLARSHIP.

(Founded in 1918 by Mr. H. Spence Thomas for the encouragement of the Members of the Associations of Students of the Institute.)

The interest on £1,000 5 per cent. War Loan Stock shall be devoted to the Scholarship.

The Holder of the Scholarship must be a Member of one of the Students' Associations of the Institute, and must be a Student at one of the Colleges, Schools, or Institutions recognised as suitable by the Council of the Institute.

The Council of the Institute shall award the Scholarship upon Reports presented for its consideration by the Heads of any of the above Colleges, Schools, or Institutions, on the completion of one year's study by any student.

The College, School, or Institution shall present an annual Report to the Council on the work and progress of the Scholar to whom the Scholarship shall have been awarded, and the Council retains the right of withholding or cancelling the Scholarship, if in its opinion the progress of the Scholar is unsatisfactory.

In the award of the Scholarship the professional knowledge and practical experience of the candidate shall be taken into consideration.

No candidate will be elected to the Scholarship until he has satisfied the Council that his physical condition is satisfactory.

The Scholarship shall be awarded for a term of one, two, or more years in the discretion of the Council. The Scholar to briefly report at the end of each year upon the work accomplished.

The Council reserves the right to withhold the Scholarship if no candidate of sufficient merit presents himself.

1919–1921. The Spence Thomas Scholarship of £50 per annum was awarded to Mr. William John Gilbert, Nantyglo, for a period of three years, tenable at the School of Mines, Treforest.

INSTITUTE SCHOLARSHIP IN ENGINEERING.

Granted by the Council in 1921, and tenable for three years at the UNIVERSITY COLLEGE OF SWANSEA.

Session 1921-1922 to 1923-1924. A Scholarship of £70 per annnm, awarded to Mr. John Brook Fortune, Swansea.

ADVERTISEMENTS.

For particulars of advertisement space in these publications, apply to The Business Statistics Company, Ltd., Baltic House, Cardiff.

CONTENTS.

No. 6. VOLUME XXXVII., issued Jan. 20th, 1922, price 10s.

Exhibition of Fuel-saving Appliances at the Institution, November 17 to 19, 1921.

PRIOR to the General Meeting of the Institute, held at the Institution, Park Place, Cardiff, on Thursday, the 17th November, the President (Mr. W. Forster Brown, M.Inst.C.E.) opened an exhibition of fuel-saving appliances, to which the leading makers in the country had sent the latest types. A thoroughly representative and probably unique collection was set out in the library and other rooms of the Institute, and during the time it was open for inspection—Thursday, Friday, and Saturday, November 17, 18, and 19—attracted many visitors.

The President. In his address in the Library at the opening of the Exhibition the PRESIDENT said :—' I do not propose to make you a long speech. You will learn a good deal more by looking at the exhibits than from anything I can say ; but I should like to point out that fuel saving is of paramount importance to this country at the present time. We are a country that has been built up on cheap fuel. The development of our abundant resources has enabled us in the past to manufacture cheaply and to compete successfully. Now that our collieries are getting deeper and more difficult to work, involving increased cost of production, it behoves us to try and balance that by using less fuel per unit of production. I say " unit of production " because, as you know, it does not mean that we are going to use less fuel in the aggregate. All experience points to the fact that if you cheapen your cost of production, you widen your demand.

' Recognising the importance of the subject, the Council of

The President. this Institute has arranged this Exhibition, and invited people who have specialised in fuel-saving apparatus to come here and show the progress that has been made in recent years in that direction. I should like to take this opportunity of thanking the exhibitors, who have gone to much trouble in getting together so useful a collection of boiler-house appliances and accessories as we see here, and of expressing the hope that the result will be mutually beneficial to the manufacturer and the steam user. The Exhibition will remain open for three days, and, in addition to business friends, we hope it will be inspected by the members of the Students Associations affiliated to the Institute, and that they will learn all they can from what they see. I have much pleasure in declaring the Exhibition open.' (Applause.)

Amongst those who attended the brief opening ceremony were the following Past-Presidents of the Institute :—Dr. H. K. Jordan (Honorary Member), Mr. T. H. Deakin, Mr. W. D. Wight, Dr. Galloway, Mr. Wm. Stewart, Mr. Hugh Bramwell, Mr. E. Dawson. There were also present Mr. David E. Roberts, Mr. Wm. Johnson, Mr. Theodore Vachell, and Mr. H. Spence Thomas, Vice-Presidents ; and Prof. Geo. Knox, Mr. T. Sugden, Prof. Frederic Bacon, Mr. W. O'Connor, Mr. J. W. Davison, Sir Leonard Llewelyn, Mr. J. W. Hutchinson, Mr. E. L. Hann, Mr. D. F. Davies, Mr. Trevor F. Thomas, Mr. David Hannah, and Mr. B. Nicholas, Members of Council.

PROCEEDINGS.

An Ordinary General Meeting of the Institute was held at the Institution, Cardiff, on Thursday, November 17, 1921.

The chair was taken by the President, Mr. W. Forster Brown, M.Inst.C.E.

The minutes of the Ordinary General Meeting held at Swansea on October 6, 1921, were read and confirmed.

President for the Session 1922.

The President stated that the Council had elected Mr. David E. Roberts as President for the next year. (Applause.) No words of his were necessary in commendation of Mr. Roberts. They all knew his capabilities as an engineer, and were aware of the great and active interest he had taken in the affairs of the Institute for many years. **The President.**

Election of Office-Bearers.

To fill the vacancies occasioned by the retiring office-bearers, the following were elected for the session 1922 :—

Vice-Presidents.

Mr. W. W. Hood . . . . . . Cardiff.
Sir Leonard Llewelyn, K.B.E. . . Newport.

Members of Council.

Mr. J. C. Davies	Gowerton.
Mr. J. W. Hutchinson	Tondu.
Mr. Howell R. Jones	Dowlais.
Mr. C. A. Seyler, B.Sc.	Swansea.
Mr. Thomas Sugden, Wh. Sc., M.I.Mech.E.	London.
Mr. G. D. Budge	Llanbradach.
Mr. Percie O. Ward	Porth.

Election of Members.

The following candidates for admission to the Institute were declared to be duly elected :—

As Members.

Davies, John Lloyd, M.C., B.Sc. . .	Swansea.
Isaacs, Reginald George . . .	Swansea.
Mason, William	Cardiff.
Morgan, Samuel Evans	Clifton, Bristol.

Swansea University College Association of Students of the Institute.

As Associates.

Fiander, Charles Mac	Sketty, Swansea.
Fiander, Stanley	Sketty, Swansea.
Gardiner, W. A. C.	Llansamlet.
John, Theophilus	Llansamlet.
Richards, H. E. G.	Llanelly.
Twigg, George	Swansea.

As Students.

David, Trevor	Pontrhydyfen, Port Talbot.
Fortune, J. B.	Swansea.
Harris, W. H.	Swansea.
James, Ralph	West Cross, Swansea.

Boiler House Management.

The President said the next matter was the paper by Mr. David Brownlie on Boiler House Management (*vide Proceedings*, Vol. XXXVII., No. 5, pp. 405 to 438). In the first place Mr. Brownlie would give a synopsis of his paper, and show a series of lantern slides illustrating the subject. The paper was under six special headings, and to facilitate discussion and keep it within reasonable dimensions, speakers were asked to take the sections separately in the order in which they appeared in the paper, and to limit their remarks upon each branch of the subject to ten minutes. **The President.**

The Discussion.

Mr. Brownlie having exhibited lantern slides, with a running explanation of their features, **Mr. Brownlie.**

Mr. W. O'Connor opened the discussion. He said the paper was a very timely one, although the substance dealt with, fuel, was not so valuable now as some twelve months ago. It was a paper which would richly repay careful and continued study, and one which would help to mould their future practice. **Mr. W. O'Connor.**

The paper, while comparing the two dominant types of boiler somewhat extensively, appeared to him to have left out

Mr. W. O'Connor.

of consideration one of the factors (in the speaker's opinion one of the vital factors) governing the choice of type; he referred to the fuel which would be used in the boiler. As colliery people, they had a very fair idea when they laid down their boilers as to the fuel they would like to burn. They might not, at all times, be able to carry out to the full what they had planned, owing to unforeseen circumstances, but he thought it would be conceded that, in studying the matter with a view of deciding which type of boiler they would adopt, it was highly desirable that regard should be had to the fuel they expected to burn in those boilers. He thought the statement that inferior fuels, from the fact that there were no carriage charges to pay, could be burned at the mine to greater advantage than anywhere else, was a perfectly sound one. Most collieries would desire to burn fuel which had the lowest market value, consistent with keeping the wheels going, and in order to do that most engineers would agree that it was desirable to have a large furnace with a suitable draught. In fact he (the speaker) looked upon the problem of the furnace as being the main one in connection with boilers. As had been mentioned in the paper the Lancashire boiler was a good boiler, which had been extensively adopted, and had given very good service; and, provided they were prepared to pay for a good class coal, a good case for its adoption could be made out in many instances. But when colliery managements proposed to burn refuse fuel, necessitating frequent cleaning of the grates, he found the very confined furnaces characteristic of this type were a drawback, and he thought that the use of this fuel made it desirable that the grate should be a large one. In the case of low grade fuels difficult of ignition the limitations of the internal grate were absolutely prohibitive. It was true that attempts had been made to cope with this disadvantage in several instances in the district by the external furnace, but

Mr. W. O'Connor.

the practice did not survive, and he thought it was a fair inference that it was not altogether successful.

He would like to point out that the very low efficiency of the egg-ended boiler was early appreciated in this coalfield, and for a very long period of years this type was practically superseded first by the internally fired type and in later years to a constantly increasing extent by water-tube boilers of great capacity.

He recalled the case of a colliery where seven egg-ended boilers used a large quantity of coal, and it was decided to replace them by three Lancashire boilers. Some shortage of steam was experienced during the period while one of the egg-ended boilers was being removed and one of the Lancashires put in its place ; but when this was done, it was found possible to dispense with the other six and keep the pit going with the one Lancashire. The saving in tons consumed was very great, but it was also found that it was necessary to give the Lancashire good marketable small coal. A further attempt at economy was made by retaining the large furnace of the egg-ended type and fixing a Cornish boiler above the furnace, taking the gases back through the tube and around the boiler. No exact tests were made, but it was considered that the results were better than the Lancashires. The practice had to be abandoned in consequence of the danger caused by the deposit inside the boiler settling on the hottest part of the plate over the fire, causing risk of rupture. Another case having some bearing on the question was one where gases from a range of coke ovens were passed beneath and around egg-ended boilers with only moderate results. The boilers were replaced by Cornish boilers with considerable gain. Some years later water-tube boilers were installed, when double the evaporation was secured from the same gases. There could be no doubt that the subdivided mass of the water in the tubes,

Mr. W. O'Connor.

and the thinness of the material of the tube as compared with a boiler plate, were the factors in achieving this result, and the gain was the more marked in the case of a low gradient heat, as in this case.

While the better fuels will always give the best comparative results when used at a distance from the source of supply, due to the smaller incidence of the charges for carriage and handling, the speaker considers the relative advantages, under the circumstances he has mentioned, of boilers which allow of fuels of low value being burned easily, are very great, and would suggest that economy is more likely to be realised by the adoption of such boilers in suitably large units, fitted with furnaces designed to ignite the fuel easily by the use of combustion arches and brick walls, so as to ensure complete combustion before the gases come into contact with a cooler surface; with the further consideration that forced draught and labour-saving arrangements are much more easily added in such installations.

Mr. Thomas Sugden.

Mr. Thomas Sugden, Wh. Sch., London, thought that, although he anticipated sharp criticism in regard to certain parts of the Paper, there could be no difference of opinion in respect to its value.

The chief merit of the Paper, he considered, was due to the fact that the results given of numerous tests by the author were made under actual working conditions, and not by trained operators under favourable conditions with excellent coal, a clean boiler, and all preparations for making a test which would show the highest efficiency. Under such circumstances very much better tests were obtained than were actually found under normal working conditions.

In analysing the results given on p. 413, it was interesting to note certain omissions. No account had been taken in these tests in regard to moisture and priming, and consequently

Mr. Thomas Sugden.

the results as regards efficiency might be misleading. The tests, however, clearly indicated the direction in which economy was obtained.

The best results were obtained where the furnace grate had been reduced within reasonable limits. It was well known that to increase the grate area frequently meant less steam was raised, and that greater waste resulted owing to the impossibility of controlling and keeping in good condition a long furnace.

It was also indisputable that the best results were obtained in boilers where the greatest amount of coal was burned per square foot of fire grate.

With regard to the percentages of CO_2, it would be interesting if the author would state the point at which the records were taken. If taken in the down-take only the results of combustion were indicated, and if taken at the chimney base this would indicate air leakages; possibly the better plan was to take records both in the down-take and at the chimney.

With respect to the relative efficiency of economisers and superheaters, some explanation of the figures given would appear necessary; there might be a good explanation for this, but it did not appear on the surface.

It must not be assumed that because a 14 to 16 per cent. efficiency was obtained in the economiser, and a 6 to 3 per cent. efficiency was obtained in the superheater, this represented coal saving as regards the superheater.

Economisers were of course directly concerned in helping the boiler by feeding with an increased temperature of feed water, whereas the efficiency of a superheater would not show itself at all in this table. A superheater did not add in any way to the evaporation of water, but its function was to increase the temperature of steam, and in this way steam of a higher quality was obtained, capable of yielding more economical results.

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The efficiency of superheating is an engine efficiency, and also an efficiency arising from reduction of losses in the transmission of steam which prevented condensation until all the superheat had been taken out of it, *i.e.*, the superheat may be diminished in temperature by say 100° or 150° according to the amount of superheat, without condensing into water, whereas a portion of saturated steam begins to condense into water immediately after leaving the boiler.

Types of Boilers.—Referring to the types of boilers, one noticeable omission in all the tables given by the author was that no mention was made of water evaporated per square foot of heating-surface. Information on this point would be particularly interesting, as it would indicate the value of heating-surface in various types of boilers.

The progress made in steam boiler construction followed a very definite line, and consisted almost entirely in the relation of heating-surface to grate-surface. This was clearly noticeable if they followed the improvements in boiler construction in connection with the 'Haystack' boiler, the 'Wagon' boiler, the 'Egg-ended' boiler, 'Cornish,' 'Lancashire,' 'Water-Tube,' and other tubular boilers. With each improvement the heating-surface had been increased in relation to grate-surface.

In comparing Lancashire and water-tube boilers it was difficult to explain the difference between the heating-surface and grate-surface in these two types of boilers—for example: a Lancashire boiler evaporating 10,000 lb. of water per hour would have about half the heating-surface of a water-tube boiler doing a similar duty. This might possibly be accounted for by the types of furnaces, *i.e.* the internal and external furnace.

The radiation from external furnaces must be very considerable, and must be made up by additional heating-surface.

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The radiation from the furnace of a Lancashire boiler was, of course, very small, as the furnace is completely surrounded with water.

As regards the merits of boilers, it was chiefly a question of the adaptability of various designs to various uses. Time and experience over a long number of years had to some extent decided the point, and it was quite possible that the merits of each type for any particular use might bear a definite relationship to the number of various types of boilers in use.

Speaking generally, water-tube boilers held the field for large units, and adapted themselves better to mechanical stoking, and also for supplying coal to the furnace and removal of ashes. Lancashire boilers, of course, could not be used for very large units, and mechanical stoking was a difficult problem, as well as conveyors for coal and ashes. Lancashire boilers in many cases yielded the best results, more particularly in connection with small units, and in cases where the boilers were hand-fired.

It might be remarked that high efficiency was not always worth while, as in some cases this was obtained at the expense of up-keep and repairs, which more than neutralised any saving in fuel effected.

Superheating.—The author's reference to this important subject was very brief. He had contented himself with referring to a few facts in regard to the use of superheated steam, viz., to the value of steam used with engines, and to the saving effected in the transmission of steam. His statement, however, that Great Britain was losing at least 4,000,000 tons of coal per annum through the lack of superheating was not far wide of the mark. The value of superheating was now well established, and it was recognised by engineers that the more scientific way of using steam was to use it as a gas.

In many cases little or no notice was taken of the large

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amount of water which was discharged by means of drain-cocks and steam-traps, and frequently these drains were connected to an outlet where the waste could not be observed. If it were more generally recognised that the loss of one cubic inch of water meant the loss of one cubic foot of steam, possibly less waste would be permitted to occur.

This source of waste was perhaps greater than any waste which went on in connection with the production of steam. The amount of heat which was taken to boil the water, to evaporate the water into steam, and to bring the steam up to the boiler pressure, and then to discharge a considerable percentage of the steam generated into drains, was a very important matter indeed. Such waste was practically all prevented by the use of superheated steam.

By starting with a fair initial temperature of superheat say 150° to 200° F., steam might be transmitted through long ranges of pipes, and would retain at the end some degree of superheat, which meant that it was possible at the end of a long range of pipes, to work with superheated steam under better conditions than an engine close up to the boiler when using saturated steam.

It was generally admitted that there was an economy in engine efficiency to the extent of about 20 to 30 per cent. in steam with a moderate degree of superheat; whilst 10 to 15 per cent. might be easily obtained in connection with the most modern plants, the saving with the more old-fashioned types of engines was frequently found to be more than double this. Superheated steam used in connection with heating and drying was also of very great importance, as both drying and heating were done more quickly, and with less steam than was possible when using saturated steam.

It was difficult to establish by any formula the loss of heat due to the transmission under varying conditions; in fact,

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such a formula had not yet been found. The only reliable results were those obtained from actual working conditions.

The following particulars were from actual tests :—

In a line of 10-inch piping, 2,600 feet long, made up in 30-feet lengths, and well covered with efficient non-conducting material, and passing 32,000 lb. of steam per hour, there was a drop in pressure of 8 to 10 lb., and a drop in temperature of about 90° F., with a boiler pressure of 220 lb. and a total steam temperature of 650° F.

In another case in a long range of pipes, the first length being 7 inches to a distance of 745 feet, and reduced to 6 inches for a distance of 3,695 feet, the following table shows the temperature, the distance from boiler, and the pressures. In each case the initial temperature of steam is 550° F., and the initial pressure 175 lb.

Distance from Boiler.	Diameter of Pipe.	Temperature.	Pressure.
665 feet	7 inches	504° F.	170 lb.
2225 ,,	6 ,,	428° F.	165 ,,
4440 ,,	6 ,,	366° F.	150 ,,

It would be observed that at the end of the last length of pipe referred to the superheat had disappeared.

The following limitation in regard to the use of superheated steam would be found useful, *i.e.* :

For turbines, 700° to 750° total temperature.

For drop valves, 600° to 650° total temperature.

For Corliss engines, 500° total temperature.

For slide valves, 400° to 450° total temperature.

With regard to slide valves, it was necessary to have a mechanical lubricator so as to ensure the lubricating oils being injected at the point where the steam enters the valve chamber ;

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if the lubrication was done systematically and in small doses, there was no trouble whatever in regard to the use of slide valves up to the temperature named.

It was generally recognised that the first 50° of superheat was the most effective, as it evaporated any priming water or water due to moisture in the steam. The saving in coal might generally be stated to be anywhere from 10 to 20 per cent.

In connection with recent experiments made at Messrs. Weir's Works, where they tested the consumption of steam used in their pumps, it had been found that the difference between testing with saturated steam and even 10° to 20° of superheated steam amounted to at least 20 per cent. less steam consumption.

When conditions were properly understood and appreciated there was no difficulty whatever in the use of superheated steam, and a well-constructed superheater would last as long as the boiler.

Mr. Sugden added that many cases had come under his own personal observation of superheaters having been used for twenty years without showing practically any depreciation and without having involved any expense by way of maintenance or repairs.

Mr. J. W. Davison.

Mr. J. W. Davison (Pontypridd) said he quite agreed with the author of the paper that if more scientific methods of controlling boiler plants were adopted, a saving would be effected, but it was not always practicable at collieries to exercise that control and supervision which was to be found at power-stations and large works, where everything in connection with the boiler-house was under the direction of an engineer in charge. The colliery engineer had a great variety of work to perform, and his steam plant could not always be as efficient as he would like it to be. Mr. Brownlie said that the colliery industry had

Mr. J. W. Davison.

the lowest efficiency—55·5 per cent.—of any industry. He would like to ask the author how many of the hundreds of boiler plants tested were old plants, and how many were modern. He (Mr. Davison) noticed that the efficiency at the South Wales collieries varied from 45·2 per cent. to 66·8 per cent., and that the highest efficiency in the one hundred tests were at South Wales collieries. No one could dispute the desirability of good boiler plant, but there were very many collieries where ideal conditions could not be provided without an enormous expenditure. Old plants were retained in many cases, partly on account of the expense involved in replacing them, and partly from dread of novelty entailing different and greater care of treatment. They all knew that improvements could be made in existing plants by spending money, and they would like those who took part in that discussion that afternoon to tell them what was the best way to go about it, which was the best way to obtain the great saving to which the author alluded. Of course, they were aware that each plant had to be considered on its own. It would be useful for the writer of the paper and other members if they would give particulars of the improvements which had been carried out under their own supervision. It was often a difficult problem to replace old boiler plants with new ones. At many of the old collieries there was very little space available for economisers, super-heaters, and so on without stopping the pits in order to make the change. They were told that fuel consumption at collieries varied from $2\frac{1}{2}$ per cent. to 12 per cent. of the output, but it was sometimes overlooked that the fuel used in colliery boilers was not always of the quality of the coal passed for the screens, but often consisted of mine sweepings, containing a high percentage of dirt. Therefore it was scarcely fair to say that part of the coal burnt at colliery boilers was coal of selling value. In his statistics of a hundred colliery boiler plants

Mr. J. W. Davison.

the author put the average of ash at 11·5 per cent. He (Mr. Davison) might say that it was very rarely as low as 11·5 per cent. As concentration of combustion was the main factor, there was no doubt a great deal of room for improvement and for the adoption of more scientific methods of burning coal, and it might be advantageous in some cases to have a combustion engineer, who would devote the whole of his time to the work, as was the case at some power-stations and at factories. It was difficult to get good stokers at collieries, although some of them were very good. It was difficult to get them to carry out instructions unless they were under constant supervision. It was also difficult to get them out of their old habits and introduce new methods, especially in the case of hand-firing. He hoped this discussion would bring out something that would assist them as regarded this great question of fuel economy; but, as he had said, they wanted to know how to effect these improvements.

Mr. George Roblings.

Mr. George Roblings said he could confirm Mr. O'Connor's remarks as to the type of boilers. He might mention that it would be impossible to burn coal below three-sixteenths, containing about 4 per cent. volatile, in Lancashire boilers at all, but it could be done, and was being done, in furnaces under Babcock boilers. Washed anthracite peas had been used in Lancashire boilers with good results. Generally, colliery people tried to burn fuel that they could not sell, and it was not fair in these circumstances to consider that the colliery industry had the lowest efficiency in the burning of coal under their boilers. It was to the credit of the colliery industry and not to its discredit that their figures were as good as they were. He found it exceedingly difficult to get proper data as to the burning of anthracite coal under boilers, and the results attending it. It would be a great assistance to the anthracite trade generally if something could be done in that direction, showing

Mr. George Roblings. what results might be obtained from the smaller kinds of anthracite as fuel, of which they had hundreds of thousands of tons lying on the banks. Quantities of smokeless fuel were consumed in large towns, but as 80 per cent. of the boilers in this country were Lancashire boilers, a cheaper class of coal could not be used; but if more water-tube boilers were introduced, with large furnaces, there would be a greater demand for smaller size fuel.

Mr. G. D. Jones. Mr. G. D. Jones said, taking the figures in the paper, he summed them up as follows:—Taking 300 working days to the year, and taking the quantity of coal given per annum, together with the number of boilers, the quantity of coal burned per boiler in 24 hours was, in one case, 7·2; in another, 7·3; and in a third case, 7·5. Yet Mr. Brownlie stigmatised collieries as being the most wasteful of all industries. His own experience showed it to be $5\frac{1}{2}$ tons; so there must be some discrepancy somewhere. And they did this with coal they could not send to market. The author's figures worked out at $7\frac{1}{4}$ tons, which he (Mr. Jones) considered excessive.

Mr. H. Davies Mr. H. Davies said that Mr. Brownlie deserved their thanks for the very good paper he had put before them, and also for the manner in which he showed that the results obtained from colliery steam boiler plants left much to be desired. It was shown in the table on page 413 that the quantity of ash differed between the colliery plants and the modern plants run on scientific lines by only 1 per cent. He would imagine that the difference would have been more—in the neighbourhood of at least 6 per cent. or 7 per cent. Then, with regard to the difference in the quantity of coal burnt per square foot of grate area per hour, between the colliery boilers and the ones run on scientific lines, it was shown that in the former 18·9 lb. of coal was burnt per hour against 32·1 lb. in the latter case. One would like to know the reasons for this very marked difference.

Mr. H. Davies. Would not this difference be accounted for partly by the difference in the duration of the comparative tests? In the colliery boilers test, the time was given as extending over a period of 9·68 hours, whereas in the tests on the modern plants, the duration was only 6·75 hours. Were these tests therefore a fair comparison, and would not the difference be due, to a great extent, to the intermittent or fluctuating demands on the colliery boilers, and also aggravated by the losses that occurred during the period of cleaning out the fires of the colliery boilers, which was an important factor where consecutive shifts and intermittent demands for steam existed? After reading the paper one was rather reluctant to stand up to take part in the discussion from a colliery point of view, especially if he happened to belong to such a wasteful fraternity as those connected with the generation of steam at collieries. With further reference to the table of tests shown on page 413, regarding the coal burnt at the colliery boilers and that burnt at the fires of the modern plant, would the author tell them the condition of the coal as used at both; as to the relative amount of moisture in each? For instance, the coal burnt at the colliery fires might have been loaded in wagons, and stocked thus, or in bunkers, open to all conditions of weather. Whereas the coal consumed at the modern plant might and probably would be in covered bunkers and was much drier. He would like to know what was the real cause of such poor results as shown by the test on colliery boilers, so that they might benefit from such knowledge.

Mr. W. Browning. Mr. W. Browning (Wattsville, Cross Keys) said he appreciated the manner in which Mr. Brownlie had dealt with a very difficult proposition in comparing the Lancashire boiler with the water-tube boiler. It was a very narrow plank, and he had walked it warily. They had to accept conditions as they found them at the collieries. His own experience with

mechanical stokers was that if they had high-grade fuel, and had the thickness of fire and size of grate according to their steam requirements, they could get a high efficiency, but if they had to use a low-grade fuel, and had an erratic demand for steam, and not a constant demand, and they tried to speed up, they had either to slow down the grates or reduce the thickness of fire, which immediately lowered the efficiency of the boiler. Then they had the colliery manager coming along to complain. With an adequate installation of Lancashire boilers and good hand-firing, they could get good results. He noticed that the boiler inspectors seldom 'inspected' the men firing the boilers. The fact was, it was as necessary for a stoker to be trained as in the case of the carpenter, fitter, or blacksmith. When a stoker was off ill, or died, they too frequently said, 'We'll get one from the navvy gang.' (Laughter.) The question of the human element in the stoke-hole was most important. Attention should be paid to the training of men handling the boilers, as well as to the efficiency of the plant. **Mr. W. Browning.**

Mr. W. H. HEPPELL (Bridgend) said colliery boilers were kept going more or less all the year round, and at the week-end there was not adequate time to pay attention to them. **Mr. W. H. Heppell.**

Mr. W. JOHNSON (Tondu) asked what the author would consider a proper staff to look after, say, two batteries of six boilers each. It was almost impossible for the mechanical engineer at a colliery to find reasonable time to devote to the boiler plant, his work being so scattered. What did Mr. Brownlie suggest as a justifiable outlay to secure proper control of boiler plant? He quite conceded, in view of the enormous waste, that it would pay to have proper supervision and control of the boiler plant at the colliery. **Mr. W. Johnson.**

Mechanical Stoking.

Mr. W. J. Cole. Mr. W. J. Cole (Aberaman) said he was a mechanical engineer, and knew the difficulty of finding efficient stokers for hand-firing boilers. Mr. Brownlie had said that under present average conditions mechanical firing had the advantage.

The President. The President: Are you on the question of mechanical stokers now?

Mr. Cole. Mr. Cole: Yes.

The President. The President: We have not reached that section of the discussion yet. But if no one else wishes to speak on the question of types of boilers, you may continue.

Mr. Cole. Mr. Cole said his experience showed that for a large number of boilers mechanical stoking was the best proposition in colliery work or power-station work, provided they had a proper type of stoking plant. He did not say they could get such a stoking plant on a Lancashire boiler as on a tubular boiler. With a tubular boiler at collieries they could burn coal with mechanical stoking plant which it was impossible to burn by hand-firing. He thought figures would show a considerable saving by mechanical stokers over hand-firing after paying the capital outlay and the cost of wear and tear.

Mr. F. F. Evans. Mr. F. F. Evans (London) said this was an interesting paper on account of the many tables which the writer gave, but it was unfortunate that there were practically no tables which dealt with modern boiler house management, and the results obtained therein. Averages of results which applied to such varying classes of boilers as the internally fired boiler and the externally fired boiler, jumbling them all together, were not very helpful. The writer did not yet seem to have appreciated the fact that modern development of boiler house practice for any size of plant was taking place exclusively on the water-tube boiler side. He seemed to have been misled

to some extent by numerical comparison. He referred, under the heading of 'Mechanical Stoking,' of water-tube boilers, say 10 per cent., and cylindrical boilers 85 per cent., but this ignored the very vital point that, in modern practice, one water-tube boiler was equivalent to from five to ten of the old Lancashire boiler type, *i.e.*, the equivalent in output, and its coal-burning capacity was, of course, correspondingly large. **Mr. F. F. Evans.**

It also seemed that as the paper was to be read before the engineers of that section of the country where the chemical constituents of the coal were so entirely different from those on which the figures given in the paper were obviously based, sufficient attention had not been paid to the peculiar requirements of the local engineer. It was a matter of common knowledge that the burning of Welsh steam semi-bituminous and anthracite coal, which constituted probably 95 per cent. of the coal used for boiler purposes in South Wales, afforded entirely different problems to the burning of Midland, North Country, or Scotch coals, and, speaking from the mechanical stoker maker's point of view, he (Mr. Evans) thought that this had been one of the reasons which had led to such continual failure in the past of the mechanical stoker in South Wales. It was true that it had to tackle the problem of the internally fired boiler, for which it was particularly unsuitable, but it was unfortunate that the result of this experiment had been very largely to prejudice the whole case for mechanical stoking in South Wales, even when applied to water-tube boilers. It was certain, too, that in the past the efforts which had been made by certain stoker makers to tackle the problem for the water-tube boiler had led to the installation of a system which, in his opinion, had been a constant source of waste in the production of steam in South Wales. It was almost a truism now that if Welsh coal was to be satisfactorily burned on large water-tube boilers, it could

Mr. F. F. Evans.

only be done by a system of forced draught—not steam jets, but fan draught, and the employment of heavy induced draught at the back of the boilers to assist in the combustion of the coal had been, comparatively speaking, a failure. He noticed that the writer in his paper dealt very lightly with the question of draught, and had comparatively little to say on the question of fan draught, and seemed to incline very much indeed to induced draught as a solution of the problem.

In view of the fact that an induced draught system had to provide not only the draught necessary for taking away the products of combustion from the furnaces of the boiler, but had to maintain sufficient suction throughout the whole boiler system and its connections to overcome the resistance of the grate and the fuel bed, with the result that in addition to the air required for good combustion, excess air was admitted through infiltration, it was obvious that the running charges on such a plant must be very much higher than where forced draught was employed, giving the properly proportioned quantity of air required for the combustion of a given amount of coal. It would seem, therefore, that the case for forced draught was so amply established, as was shown by the results which were continually being obtained in this field, that all that was necessary now was to determine which system of forced draught combined with mechanical stoking was likely to give the best results.

Mr. Brownlie in his paper, when speaking of forced draught, gave as one of its disadvantages that it took from 2 to $2\frac{1}{2}$ per cent. of the steam production of the plant to work the fan, but he could assure him that with a modern system the cost of the production of the forced draught and the driving of the mechanical stoker could be done for less than one-half of one per cent. of the steam raised on the boiler, and that consequently, in those cases where such high efficiencies as 82–84 per

cent. were being guaranteed, the net efficiency guaranteed was that figure less one-half per cent. Mr. F. F. Evans.

This brought him to another point. The comparative efficiencies given in Table 19 were very misleading, as here again they did not separate the types of boilers on which these efficiencies had been obtained; but if they examined the figures given for the 80 plants mechanically fired, from the point of view of CO_2, it was obvious that, in spite of the writer's expressed opinion that there was, in practice, little difference in efficiency on all of the boiler plants between hand fired and mechanically fired plants, the percentage of CO_2 figures he gave showed indisputable supremacy to the mechanically fired plant. It would take too long, and would mean, in fact, the writing of a complete paper supported by figures, to controvert his statement with regard to the efficiency obtained with mechanical stokers. The speaker had had some years of experience on the practical side, had run a large number of tests on both internally and externally fired boilers, hand fired and also stoker fired, and was prepared to state definitely that, as the result of many hundreds of tests, the mechanical stoker, if properly run, was a more economical proposition than even the best of hand firing when comparison was made over long periods. As a matter of fact, hand firing sooner or later was bound to disappear. It was increasingly difficult to get men to undertake this laborious work, and it was not so difficult to get men who could properly supervise an installation of mechanical stokers. It was for this reason also, in his opinion, the Lancashire boiler in South Wales was also bound sooner or later to disappear. It could not be shown that it was more efficient than the water-tube boiler, and it could be definitely shown that with mechanical stoking and inferior coal—the water-tube boiler could use grades of coal which the Lancashire boiler could not look at—the water-tube boiler was the most economical.

Mr. F. F. Evans.

The writer of the paper seemed to have got his knife very considerably into the Coal Controller as to his recommendation to colliery owners to install mechanical stoking. His (Mr. Evans') feeling in the matter was that, apart from any extension of business which might have accrued to his Company, he should have been only too pleased to see the Coal Controller given such powers as would enable him to take recalcitrant colliery owners 'by the scruff of the neck,' and compel them to put in plant for the burning of their own waste coal. Some of the largest companies in South Wales were the worst offenders in this respect, and were every year using thousands of tons of good-class coal which they could sell at a good price, and sending stuff to the tip which, mechanically stoked, would give them all the steam that they required.

It was true that there were several grades of Welsh coal which offered certain difficulties to the mechanical stoker, but here again methods could be found, by means of powdered fuel, to utilise thousands of tons of stuff which at present simply went to the tip.

With the other points in Mr. Brownlie's paper he was in entire accord. The necessity for the employment of suitable means of taking up the waste heat from the boilers, the heating of feed water by the utilisation of exhaust steam, and the employment of the necessary instruments to enable the engineer to see whether waste is going on, were all highly desirable features of a modern boiler house plant, but the main way in which coal could be conserved in a boiler house, and economy made, was undoubtedly on the boiler house floor and in the furnace of the boiler itself. He might say here that, while the battle of the Lancashire type as against the water-tube type was a very interesting one, as mechanical stoker makers his Company were interested largely in the question of *furnace efficiency* and the proper

combustion of the coal. Within reasonable limits, all types of water-tube boilers at present on the market were good heat absorbers, and capable of giving decent boiler efficiency, provided they could be kept clean, inside and out; but the crux of the whole matter was the question of furnace efficiency as measured by percentage of CO_2 in flue gases and the amount of combustible which was contained in the ash, provided they were not paying too much in power consumption to obtain these results. It was possible to equip a modern boiler plant with such machinery as would enable coal to be handled on to the furnace, through the furnace, and away to the ash dump without the intervention of human labour in any form whatever, and to do this at rates of power consumption which could be expressed in terms of one-half of one per cent. of the total power raised in the boiler house. **Mr. F. F. Evans.**

Incidentally, in his opinion, the complication of balanced draught was an ugly, wasteful means of producing high efficiency, but he looked forward to the time when on the new boiler units which were being increasingly put down they would see a type of boiler and economiser adopted which it would be possible to work in conjunction with a natural draught chimney, so that the wasteful continuous running of induced draught could be entirely eliminated.

The statement that the average Lancashire boiler plant—boilers, economisers, and super-heaters—was working at about 60 per cent. efficiency was nearly correct, but the figures for the average water-tube boiler plant of 69 per cent. were below the average. It was extremely difficult to make any comparisons owing to the varying nature of the plants, and it was noticeable that the writer of the paper said nothing as to the conditions of the load factor which were so important when determining the question of efficiency; but where the load factor was reasonably high there should be no difficulty what-

Mr. F. F. Evans.

ever in maintaining throughout a week's run an efficiency of 75 per cent. on a properly controlled and equipped modern generating station, even when burning a low grade of fuel.

As to the *amount of steam produced*, the claim referred to, that mechanical stoking increased the steam output of the boilers, was amply borne out by repeated tests. It was, of course, not wise to take an isolated case, but it would be very interesting to see how long a fireman working by hand could maintain a 25 to 30 per cent. overload on a large water-tube boiler of say 40,000 lbs. evaporation per hour, and he ventured to say that even a gang of them, at the end of an hour, would be absolutely exhausted. On the other hand, it was not an uncommon thing for a mechanical stoker to jump the load on a water-tube boiler up to 30 per cent. overload without the slightest difficulty, and in the course of not more than 10 to 15 minutes. This assertion dealt entirely with the statement that it was a difficulty of mechanical stoking that it would not respond to sudden and erratic demands for steam as well as hand firing.

As regards the flexibility in the quality of fuel used, it was stated that this was a difficulty of mechanically firing boilers, that it reduced the flexibility of the plant. Here again he was not at all in accord with the writer. If machines existed, as they did, which would deal with such varying classes and grades of fuel as bituminous slacks, nuts, Welsh steam smalls, anthracite peas and beans, coke oven breeze and gas coke breeze, it was obvious that the flexibility of mechanical stoking was larger than the writer of the paper had assumed.

With regard to the various kinds of fuel apt to be thrown into the colliery fire hole, this could easily be dealt with if the coal was graded or crushed. A great deal of it did not need to be crushed, as it came in such a form that it could go straight on to the stokers, but it had been found in colliery practice

that, by the utilisation of crushers, large quantities of coal which were hitherto regarded as hopelessly impossible from the boiler point of view on account of their high ash content, and the fact that they came in big bulk, had been dealt with, and were being burnt to-day with good efficiency and without the slightest trouble. It was quite true that there were certain grades of Welsh coal which could be best dealt with in other ways than by mechanical stoking, but that was a problem which, in his opinion, needed separate consideration. **Mr. F. F. Evans.**

As to repairs and brickwork upkeep, it was often urged that in this respect the argument was entirely in favour of the Lancashire boiler. So it was, if item was put against item, but if the larger view was taken, and the cost of upkeep, repairs, and *labour* for firing and ash handling was brought into account, then for a similar output of steam on the basis of, say, 40,000 lb. of steam an hour the modern water-tube boiler, with coal handling, mechanical stoking, and ash handling of the most modern design, would show a handsome balance in economical working on labour alone, and the return on capital invested was of such a nature that it could be expressed in terms of 20 or even more per cent. On larger plants the return was even greater. It must not be overlooked in this connection that on the figures given in the paper the output of the Lancashire boiler was not more in average working than two-thirds of its rated capacity, and the question of a 25 or 50 per cent. overload could never be considered. This was another reason why the water-tube boiler was increasingly favoured. They paid £100 and got in value at least £100 and sometimes £150. With the Lancashire boiler they paid £100 and got in value about £75.

Mr. Evans gave a summary of the following results of boiler trials made at the Bristol Corporation Electricity Works:

Result of Boiler Trials made at the Bristol Corporation Electricity Works.

Water-tube Boiler by Messrs. John Thompson Water-tube Boiler Ltd., Heating Surface of Boiler 5,400 *sq. feet, Heating Surface of Superheater* 540 *sq. feet. Self Contained Travelling Grate Stokers by Underfeed Stoker Co. Area of Grate Surface* 114 *sq. feet.*

	Date of test . . . Name of coal . . .	October 26, 1921. GLAMORGAN SMALL (Welsh).		October 27, 1921. GLOUCESTER SLACK.		October 28, 1921. COKE BREEZE.	November 2, 1921. MONMOUTH (Welsh).	November 4, 1921. ANTHRACITE GRAINS.		November 5, 1921. MONMOUTH (Welsh).
	Analysis of Coal .	Ash . . 14·03% Volatile . 17·48% Moisture . 1·24% Fixed carbon 67·25% B.T.U. as fired 12,268		Ash . . 12·64% Volatile . 19·15% Moisture . 1·28% Fixed carbon 66·93% B.T.U. as fired 13,138		Ash . . 25·03% Volatile . 6·82% Moisture . 13·68% Fixed carbon 54·47% B.T.U. as fired 8,927	Ash . . 13·17% Volatile . 21·04% Moisture . 1·70% Fixed carbon 64·09% B.T.U. as fired 12,683	Ash . . 22·55% Volatile . 7·94% Moisture . 1·94% Fixed carbon 67·57% B.T.U. as fired 10,790		Ash . . 15·79% Volatile . 27·46% Moisture . 1·93% Fixed carbon 54·82% B.T.U. as fired 11,851
	Duration of trial . hrs.	6 full load	1 overload	6 full load	1 overload	6 full load	6 full load	6 full load	1 overload	4 full load
Pressure	Steam gauge . lb.	202	205	200	210	200	200	200	200	200
	Draught gauge, damper inches W.G. . .	0·5	0·5	0·5	0·5	0·3	0·3	0·3	0·3	0·3
	Absolute steam pressure . . . lb.	216·7	219·7	214·7	224·7	214·7	214·7	214·7	214·7	214·7
	Air pressure in windbox	0·5	0·8	0·6	0·8	0·6	0·6	0·6	0·7	0·5
Temperature	Gases leaving boiler °F.	577	575	555	570	553	510	590	590	610
	Feed water entering boiler . . °F.	135	127	100	100	240	90	96	100	100
	Steam . . °F.	522	527	562	566	538	553	568	568	548
	Superheat . . deg.	139	143	174	174	150	165	180	180	160
Fuel	Total fuel consumed lb.	18,144	3,472	16,128	2,912	19,264	12,880	18,256	3,136	11,984
	Total refuse dry . lb.	2,916	439	2,038	368	4,956	2,053	4,928	980	2,164
	Total refuse dry per ct.	16·07	12·64	12·64	12·64	25·72	15·93	27·02	31·25	18·05
Fuel per hour	Fuel as fired per hr. lb.	3,024	3,472	2,688	2,912	3,211	2,147	3,043	3,136	2,996
	Fuel as fired per sq. ft. of grate . . lb.	26·52	30·45	23·58	25·54	28·16	18·83	26·69	27·45	26·28
Flue gas	CO_2 in gases leaving boiler . per cent.	13	14	12	11·5	13	13	13·5	12·5	13·5
Total water	Total weight water used . . lb.	155,106	32,000	139,400	26,000	116,000	106,000	120,000	20,500	93,000
	Factor evap. boiler, including superheater .	1·21	1·22	1·27	1·27	1·11	1·27	1·27	1·27	1·26
	Total from and at 212° including superheater . . lb.	187,678	39,040	176,038	33,020	128,760	134,620	152,400	26,035	117,180
Water per hour	Amount used . lb.	25,851	32,000	23,233	26,000	19,333	17,666	20,000	20,000	23,250
	Evap. from and at 212° including superheater . . lb.	31,279	39,040	29,506	33,020	21,459	22,436	25,400	26,035	29,295
Economic Evap.	Evaporation per lb. actual . . lb.	8·51	9·21	8·64	8·93	6·02	8·22	6·57	6·53	7·76
	Equiv. from and at 212° including superheater . . lb.	10·31	11·23	10·97	11·31	6·68	10·44	8·34	8·29	9·78
	Evap. from and at 212° per sq. ft. heating surface . lb.	5·79	7·22	5·46	6·11	3·97	4·15	4·7	4·82	5·42
	Efficiency of boiler .	81·39%		80·79%		72·36%	79·58%	74·73%		79·77%

Mr. J. Geldard (Bolton) said Mr. Brownlie spoke of scientific control of the boiler house as if it were something new. So far back as 1897 a firm with which he (Mr. Geldard) was connected introduced scientific control of their boiler plant. That firm was now part of a combine which had between 300 and 400 Lancashire boilers at work, all under scientific control. The big textile firms in the North had their testing staffs, who would laugh at the 50 and 60 per cent. efficiency which Mr. Brownlie said was so common. As long ago as 1897 he was getting 81·3 per cent. with economiser, and 76 and 73 per cent. with boiler only. He had over 20 years' experience of mechanical stokers, and 70 per cent. efficiency was regarded as low; they were not satisfied with 70 per cent.—they wanted 75 and 80 per cent. Taking Mr. Brownlie's figures on page 421, the upper table showed mechanical firing $27\frac{1}{4}$ per cent., mechanical firing plus hand firing 21·6 per cent., showing that hand firing must have been below 21·6 per cent., as the mechanical stoking figures were higher. Again, at the bottom table—mechanical firing 19 per cent.; the two combined 8·4 per cent.; and the last two items—the very poor figures—mechanical firing 51 per cent., mixed 66 per cent. Then over the page, amount of steam produced, the author stated that in averages there was little or no difference between hand and mechanical firing in that respect; that the average figure for the 80 mechanically fired boilers was 6,000 lb. evaporation per hour for Lancashire boilers $30' \ 0'' \times 8' \ 0''$. He (Mr. Geldard) might say that it was a common thing at that time to get 16,000 or 17,000 lb. of steam per hour on a $30' \ 0'' \times 9' \ 0''$ Lancashire boiler. They were, of course, burning good coal, which happened to be fairly cheap, with $3\frac{1}{2}$ per cent. ash. To get below 15,000 lb. on any particular boiler meant that work was dragging somewhere, and inquiry was made in the stoke-hole. At the Lancashire and Yorkshire power station they got close on 18,000 lb. on a

Mr. J. Geldard. 30′ 0″ × 8′ 6″ Lancashire boiler. At Formby, on the peak loads they got well over 15,000 lb. of steam per hour per boiler ; so that 6,000 lb. was an absurd figure. Tests at the Cambrian Collieries within the past few weeks showed that the mechanical stoker gave 88 per cent. more steam than by hand firing, and a nett gain of fuel of 22 per cent. Mr. Brownlie's figures seemed strange to him in the light of his own experience up and down the country with his own class of stoker. As to Mr. Brownlie's statement on the flexibility of steam output, that it was a defect of mechanical stoking that it would not respond to sudden and erratic demands for steam as well as hand firing, this also was absurd according to his experience. As to the flexibility in quality of fuel used, he failed to see that the mechanical stoker could not deal with varying qualities of coal ; there were very few which could not be dealt with. He had known four or five qualities of poor-grade coal dumped into the yard and indiscriminately mixed, and used efficiently at the boilers with mechanical stokers. Mr. Brownlie talked about uniformity of quality. Did he mean in size or quality ? Uniform quality they were not particular about, but they were about uniformity of size. As to steam jets, they agreed. Just as in the case of motor-cars and mechanical stokers, steam jets needed the exercise of care. If looked after, the amount of steam used should never reach 21½ per cent., as cited by Mr. Brownlie, and not more than 3 per cent. Such a figure meant blank carelessness of those using them. As to cost of labour, it was quite a common thing for mechanical stokers to halve the cost of labour of hand stoking. He had a case in mind in that district where one man did, comfortably, work that had needed three men hand firing. As to capital outlay, interest and depreciation, Mr. Brownlie's figures seemed to overstate the case against mechanical stoking. The initial cost of the machine was saved in a year or two, in which case they might surely allow something for upkeep.

Mr. W. Whittaker.

Mr. W. Whittaker, junior (Burnley), stated, with reference to black smoke, that the author's statement that mechanical stoking was superior to hand firing for the prevention of black smoke required a little explanation. Did Mr. Brownlie mean the mechanical feeding portion of the stoker or the whole mechanical stoker fitted to mechanical grates? Because it was possible to abate this nuisance with hand firing in conjunction with suitable mechanical grates. As to the cost of up-keep (on page 424), the author stated: 'There is bound to be considerable up-keep when the moving parts of a machine are in contact with a red-hot furnace.' This required qualifying. To his (the speaker's) mind it depended upon the construction of the furnace, the amount burned, and the fuel used, and lastly the human element. He knew of mechanical furnace grates which had been in continuous operation for five to ten years, burning all sorts of fuel, both good and inferior, which had not cost one penny for renewals, including the grate bars, and their condition to-day was exceedingly good. The excessive up-keep of some furnace-grates and mechanical stokers was caused to a great extent through faulty and flimsy construction, owing to lack of sound engineering knowledge by the designer. It also very often happened that the inventor had spent a good deal of money in carrying out experiments with his appliance, and was anxious to get a return of the money so spent; consequently, machines were turned out which were not standardised—which resulted in their condemnation through the time and trouble spent in fitting new parts when this became necessary. The obvious remedy was for manufacturers to standardise the standard parts and make those parts substantial when the experimental period was finished. The excessive consumption of steam by the jets in forced draught furnaces could be reduced to minimum proportions by a correct design of the throat

Mr. W. Whittaker.

opening in the bar, and permanently fixing the jets in the most efficient position, also making the jets of suitable material to prevent enlargement of the hole through wear and corrosion. Also the steam used for jets should be properly superheated. It might not be generally known amongst engineers that there was a definite correct position for a steam jet in relation to the throat opening in the bar, and that if this position was altered, even in the slightest degree, the efficiency suffered.

With reference to 'better conditions in the fire-hole' (paragraph 12, page 425), and the laborious work of hand-cleaning the boiler mechanical grates, the author made the statement: 'There is nothing to beat good hand firing, but the difficulty is to find it.' With suitable self-cleaning grates and hand firing, expert firemen were not required—the fuel being simply thrown on the front of the grate, immediately inside the fire door, the action of the bars distributing the fuel over the whole of the grate. As to what the author wrote on page 432, with properly designed mechanical self-cleaning grates it was not necessary to shut off the steam jet when the fire door required to be opened, but with the stationary type forced draught grate this was generally the case, especially so when the fires were clinkered up, the gases taking the line of least resistance.

Mr. W. O'Connor.

Mr. O'Connor said he would like to emphasise the point made by Mr. Browning as to the human element in the stoke-hole. The great advantage of mechanical stoking with self-cleaning grate was that they could burn fuel of low value, and get a good hot fire, without asking too much from the man in the stoke-hole. He thought there was a real difficulty in expecting a man to clean out fires more than a few times each shift.

This had recently been brought home to him one evening

a few months ago—when all the stokers, in common with other labour, cleared off; and it became a serious question to those in charge as to how they were to keep things going. All the boilers were of the same type, but some were hand fired and others mechanically fired. Under these equal conditions, no attempt was made to work the hand-fired furnaces, and they were allowed to go out. The situation was saved by novices working the mechanical grates, under direction, and the steam was kept up. Mr. W. O'Connor.

('Could not the same thing have been done with a Lancashire boiler?')

Probably it was done in many similar cases with a reasonably good fuel. They had, however, on former occasions themselves used the inferior fuel in Lancashire boilers with their trained stokers, and they succeeded in keeping the boiler warm but produced practically no steam. On the other hand there was not the least difficulty in keeping the place going with the mechanical grate.

The conditions in April last brought out more clearly the relative value of each method of stoking, and he now felt constrained to form quite a different estimate of the relative values of mechanical and hand stoking to that stated in the paper. He was convinced that, as plants tended to become larger, the burning of low value fuel would have to be tackled by mechanical stoking and hand-firing methods rejected.

Mr. G. D. Budge stated that the author of the paper had cited 6,000 lb. of steam as the average quantity evaporated per hour by Lancashire boilers. Mr. G. D. Budge.

On exhaustive tests, lasting over a period of a week, and recently carried out on a Lancashire boiler 30 feet × 8 feet, the average evaporation was 10,000 lb. of steam per hour by mechanical stoking. The engineer in charge of the test

Mr. G. D. Budge.

offered to increase this to 12,000 lb. of steam, but he was asked not to do so by the colliery official.

These results were obtained with a Bennis stoker, using unwashed coal containing 20 per cent. of ash.

As to flexibility of steam output, he did not think there was any defect in this respect in mechanical stoking. As to the quality of fuel, his experience was that a mechanical stoker would use practically any fuel which could be used by hand firing. He thought, however, that the right thing to do was to use nothing but washed coal at their boilers. If it paid the management of factories to buy washed coal, it ought to pay the colliery owner to use washed coal on mechanical stokers. They ought to deal with their inferior coal in such a way as 'to be able to make use of it.'

Mr. George Roblings.

Mr. George Roblings stated that too little attention was paid by makers of mechanical stokers to the burning of anthracite coal. He knew of only one installation for using anthracite that was undergoing any sort of test at the present time. The problem certainly offered a field for investigation and experiment. Owing to the difficulty of hand firing Babcock & Wilcox boilers, down his way they had to reduce the 9-feet length of grate, because the stokers could not throw in the coal far enough, and there was from 15 to 18 inches of blank grate. Let the manufacturers be a friend to those running anthracite collieries.

Mr. F. F. Evans.

Mr. F. F. Evans: I am quite willing to be a friend to Mr. Roblings if he will give me the chance. (Laughter.)

Mr. Roblings.

Mr. Roblings: Show us the results elsewhere first. (Laughter.)

Mr. A. J. Ashton.

Mr. A. J. Ashton (Newport) stated, in reference to the remarks on economisers by Mr. Brownlie, no one willingly fed a boiler with cold water if exhaust steam or waste gases were available. Apart from being uneconomical, cold feeding pro-

duced undesirable strains upon the plates and tubes of the boiler. In practice, feed water from exhaust steam heaters seldom exceeds 200° F. To heat the water by this means was to participate in part only. Water from the heater can be passed through an economiser, and raise the temperature to 300–330° F. before entering the boilers, the number of pipes in the economiser being proportionally less than if required to raise the temperature of the water from the temperature of the atmosphere. At collieries and steel works where the working load varied considerably the economiser was a useful adjunct to the boilers, as it provided a corresponding amount of thermal storage in the form of hot water, ready for any demand of extra power which the plant was called upon to supply. With regard to the saving effected, there were economisers in that district giving a temperature rise of anything from 80 to 270 degrees. If they allowed the rule that 11 degrees rise in temperature equalled 1 per cent. of saving in fuel, the saving effected was anything between 7·2 per cent. and 24·5 per cent. Mr. A. J. Ashton.

It was noticed that the average saving due to economisers given on page 413 of Mr. Brownlie's paper varied from 1·6 per cent. for 100 colliery boiler plants to 18·5 per cent. for the modern plant. Was not this 1·6 per cent. rather misleading, inasmuch as it rather conveyed the impression that economisers actually working only saved 1·6 per cent. of fuel? Those who had read the paper carefully knew, of course, that Mr. Brownlie had included in the 100 plants those which had no economisers at all, and it was this fact which had brought down the average saving to this fictitious figure, but it was hoped that others would not assume that the average saving from 100 economisers was as low as 1·6 per cent.

It might be of interest to know that the firm with which he was associated had within the last few years installed in

Mr. A. J. Ashton.

the S. Wales district 400 economisers; 340 were installed in connection with Lancashire boilers and 60 in connection with water-tube boilers: 260 were for steel works and other industries and 140 in collieries, or 35 per cent. of the total. He did not agree with Mr. Brownlie's statement that most economisers were installed on rule-of-thumb principles. He could assure him that such was not the case with the firm he represented, who insisted upon a very full investigation of the existing steam plant before submitting any proposals. It was the custom when possible to obtain the calorific value of the coal, the amount burned, the temperature and composition of the flue gases, the evaporation, and particulars of draught, etc. A scheme was then submitted, giving temperature rise in feed-water temperature of gases leaving the economiser, and the draught left in the main flue after the economiser was installed. The purchaser knew what return he would get on his capital outlay, and whether there was sufficient draught left in the main flue to burn the particular coal he was using.

Mr. Brownlie gave the average life as ten years, and through especially faulty attention, five years. Out of the 400 economisers just referred to there was only one to his knowledge that had been condemned after being at work ten years. It worked under the very worst conditions, being fed with cold water part of the time, and received the gases from boilers fired with coke oven gases. In this district it would be quite safe to say that the average life of an economiser was over fifteen years. There were economisers to-day working at collieries that were installed over twenty years ago. If an economiser was fed with water below 90° F., serious corrosion to the lower portion of the tubes and bottom headers was the result. It was the practice in collieries in S. Wales to make use of any exhaust steam for pre-heating the water before it entered the economiser, which tended to prolong the life of the economiser tubes. If

there was no exhaust steam or hot well water available, one of the National Circulators was very useful for pre-heating the water. If the water was bad, it was always the safest plan to treat it before it entered the economiser in a properly designed softener, and prevent the formation of hard scale in the pipes, which was difficult and expensive to remove. **Mr. A. J. Ashton.**

Mr. Brownlie recommended that scrapers be kept running all the time the gases were passing through the pipes. No hard and fast rule could be made, as all would depend upon the class of coal that was being burned on the boilers. With good clean Welsh coal it was not so necessary to run them all the time as with a lower grade of fuel; but as most industrial concerns did not burn the best of coal it was the best plan to keep the scrapers running all the time the gases were passing through the economiser. They were not so apt to stick when kept continuously running, and the small amount of power required was well expended in keeping the external surface of the pipes clean. It required about $\frac{3}{4}$ h.p. for every 100 pipes.

To prevent radiation from the top boxes, these should be covered with silicate of cotton, slag wool or asbestos in mattresses which could be easily removed for inspection. It was very important that all air leakages in the brickwork enclosing the economiser and boiler should receive prompt attention; the economiser should be covered with a suitable roof to protect it from the weather. The boiler slide dampers should be cased in to prevent air leakages between the damper blades and frames. The chimney draught should be regulated by the economiser outlet damper; if the boiler dampers were used for this purpose, the heat in the economiser chamber and in the feed-water was reduced, resulting in lower economiser efficiency. Mr. Brownlie said that cast-iron economisers could be used up to 200 lb. pressure. There were cast-iron pipe economisers being erected in a works at Cardiff to work at 250 lb. pressure.

Mr. A. J. Ashton.

Some doubt had recently been expressed as to the suitability of cast iron for extreme pressures, and the time was not inopportune for bringing to the notice of power users the following important facts. Trouble in the past due to economiser failures had been practically negligible, and had not tended to increase with increasing boiler pressures from the 60 lb. pressure of long ago to 300 lb. to-day. The reason was not far to seek, and lay in the fact that with a higher boiler pressure steam would form less easily, and therefore hammer action due to this cause was practically eliminated. The temperature of steam formation at extreme pressures was so very high that there could never be sufficient temperature difference between the waste gases and the water in the economiser to form steam in the economiser under banked conditions. This fact was very important, as it practically meant much more static conditions than would prevail in a plant working at a low boiler pressure. In face of this it was difficult to understand the attitude adopted towards cast-iron economisers for extreme pressures, when in addition to a generous factor of safety could be added a guaranteed life for many years longer than for a steel economiser. The fact must not be lost sight of that the initial thickness of a steel tube was just about half the thickness of the usual cast-iron economiser tube, and therefore even with the same rate of corrosion its life would be correspondingly shorter, but with a greater rate of corrosion, both internally and externally, this initial disadvantage was accentuated.

The latest design of economiser for meeting extreme pressures embodied some important features. In the first place, the tubes were thicker and commence their life with a factor of safety of between 15 and 20, destructive tests of tubes showing bursting pressures of 4,250 and 4,520 lb. per square inch. The headers themselves, both top and bottom, were

Mr. A. J. Ashton.

cylindrical in design, the top headers being fitted with special internal lids more suitable for extreme pressure than the standard internal lid for ordinary pressures. The principal departure in design, however, was in connection with the socket joints of the sections. Hitherto these joints had relied upon friction between the tube and header for resisting internal pressure, and although this method enabled sections to withstand extremely high pressures, the holding power had been augmented still further by the adoption of Green's patent 'ringstay' joint. This consists of an external ringplate and a split ring, which were passed over the tube end and held in contact with the shoulder of the tube by the ringplate, which was secured by four set screws. Direct pull tests had demonstrated that each of these joints was capable of sustaining a load of 20 tons, irrespective of friction. Economisers arranged 10 tubes wide and containing four 'ringstay' joints top and bottom in each section were thus rendered capable of resisting an internal pressure of 1,100 lb. per square inch over and above the friction joint. When it was realised that the conical friction joint itself was capable of withstanding great internal pressures without failing in any way, it would be understood from the above particulars that a section reinforced with 'ringstays' was capable of withstanding—with a reasonable factor of safety—all boiler pressures which are likely to become general for many years to come.

There had been recently been put on the market a cast-iron economiser of horizontal design for inclusion in a boiler casing. It contained the whole of the above alterations for extreme pressures, *i.e.*, thicker tubes and 'ringstay' joints, but embodied a further improvement whereby the whole of the sections of tubes were supported independently of each other, with the result that any section was free to expand and contract, or could be removed and replaced without interfering with

Mr. A. J. Ashton.

adjacent sections. Each section, moreover, contained only three tubes, and therefore could be handled with far less inconvenience than would be the case either when replacing a tube in position or removing a section containing a larger number of tubes. These sections of tubes could withstand pressures of 2,000 lb. per square inch without failing, and as corrosion took place mostly in connection with the tubes only, which, when new, greatly exceeded this strength, it would be fully realised that some considerable time would have to take place before these sections could be deemed unsuitable for any pressure which was likely to be met with in the near future. There might be a limit beyond which it would be inadvisable to go with regard to putting forward cast-iron for economiser work, but the above figures should serve as a convincing argument that this limit had not yet been reached, as the abundant evidence of rapid wasting and pitting of the steel tube, as compared with the proverbially long life of the many hundreds of thousands of cast-iron economisers now in existence, should be a fitting deterrent to those who would advocate the use of steel for this purpose.

Mr. Ashton went on to speak of the economiser as an investment. He said in order that the value of installing economisers in connection with boiler plants may be fully realised, it is only necessary to take a specific case of an average plant, and to show the resulting benefits. Consider, for example, a boiler plant consisting of two Lancashire boilers with a total evaporation of 15,000 lb. of water per hour, boiler pressure 200 lb. per square inch, feed water temperature 100° F., temperature of flue gases 650° F., and burning 2,140 lb. of coal per hour. Their standard size of economiser for this plant would be 224–8's 9 ft., which, under the above conditions, would give a rise in temperature to the feed water of 160° F. The total heat of the steam, at 200 lb. per square inch boiler

pressure, above feed temperature (*i.e.*, 100° F.) is 1,167 B.T.U's. **Mr. A. J Ashton.**

The theoretical saving per cent. in heat due to the economiser is :

$$\frac{160}{1167} \times \frac{100}{1} = 13 \cdot 7.$$

This saving 'per cent.' does not include the saving due to increased efficiency of the boiler itself, and therefore the gross saving due to the economiser can be taken as 15 per cent.

Assuming that this plant works 3,000 hours per annum, the saving in coal is :

$$\frac{2140}{2240} \times \frac{3000}{1} \times \frac{15}{100} = 425 \text{ tons}$$

and at 20*s.* per ton this represents a gross annual saving of £425.

Assuming the life of the economiser to be 15 years, and the above saving, less £40 per annum for running and replacement charges, to be invested half-yearly at 5 per cent. compound interest for 15 years, the total amount saved would be £8,250.

The initial cost of the economiser and brickwork, etc., would be £1,500, made up as follows :

	£	s.	d.	£	s.	d.
224–9 feet Tube Economiser . .	1,010	0	0			
Dampers, pipework, valves, engine or motor	390	0	0			
				1,400	0	0
Brickwork				100	0	0
				£1,500	0	0

The table on p. 480 shows how the nett gain is computed.

Mr. A. J. Ashton.

Comparative Balance Sheet showing commercial advantage due to an economiser which lasts 15 years and is saving fuel during that period :

Money Invested in an Economiser.	£	*s.*	*d.*	*Money Placed Out at 5 per cent. C.I.*	£	*s.*	*d.*
Sum of nett savings of £385 per annum, with accrued interest over a period of 15 years . . .	8,250	0	0	Money which would have been invested in an economiser	1,500	0	0
Sum for new economiser (existing brickwork assumed good) . . .	1,400	0	0	Accrued interest over 15 years at 5 per cent. .	1,620	0	0
Cash in hand, *plus* new economiser . . .	6,850	0	0	Cash in hand, but no economiser . . .	3,120	0	0
At the end of 15 years the economiser user is in possession of a new economiser and . . .	£6,850	0	0	At the end of 15 years the person who has not bought an economiser is in possession of only . . .	£3,120	0	0

The person who has bought the economiser has, therefore, obtained a nett advantage of £3,730, *plus* a new economiser, or an equivalent gain in £ *s. d.* of £5,130, which is equal to an annual saving of £340 over and above that which would have been obtained had the £1,500 been invested at 5 per cent.

Major S. Utting.

Major S. Utting joined the other speakers in congratulating Mr. Brownlie upon his paper, and upon the remarkable courage with which he had attempted to deal with such a large subject in a small space. Actually, each of the six sections mentioned on page 405 might easily have required a similar space, if dealt with in the light of our present knowledge.

Mr. Brownlie had discussed the merits of economisers and feed heaters, but there was another form of economiser which he had not referred to, and which was not to be regarded lightly—namely, the air heater, an apparatus or appliance which utilised the waste heat in flue gases by raising the temperature of the air required for combustion.

The speaker was a great believer in the feed-water economiser, particularly the cast-iron tube type where it could be adopted, but in view of the tendency towards high steam

pressures in the modern installation of to-day, and the much higher pressures of to-morrow, which, he predicted, might reasonably be taken as 450 to 500 lb. to the square inch, the cast-iron economiser would give way to the steel tube type, which, up to the present at least, had not been without its troubles. **Major S. Utting.**

The thermal efficiency of an installation was, of itself, no guide ; one must consider all the factors which contributed to increased efficiency—one, not the least, being capital cost.

He would attempt to explain this graphically on the blackboard, and would give characteristic curves such as would be obtained by a complete study of a particular case.

Assuming the flue gases left the boiler at 570° F., the problem was to utilise the heat in these gases and cool the latter to a low temperature before discharging them to the chimney, the temperature being, say, 300° F.

The heat so abstracted could be transferred to the boiler feed-water by the well-known economiser and, alternatively, to the air required for combustion in the boiler furnace.

Curve A would indicate heating surface of the economiser if this apparatus alone were employed. It would be seen that the cost of this method of recuperation was a maximum. Alternatively, an air heater alone could be employed, the heating surface of which would require to be greater than that of a feed-water economiser, but, owing to the low cost of the apparatus, the total cost would be a minimum as shown on Curve C.

These were the two extremes, and, unless the conditions were very extraordinary, it would no doubt be found more advantageous to use a feed-water economiser smaller than the usually accepted dimensions for a given boiler and, in addition, instal an air heater. This is indicated by the vertical XY, from which it will be noted that the boiler flue gases would enter

Major S. Utting.

the economiser at 570° F., and leave at 450° F., at which temperature they would enter the air heater, and would leave same at 300° F. The cost of this combination would be about 60 per cent. of that of a cast-iron economiser to effect the same heat transference. The feed water temperature rise would, of course, be less, but the temperature of the air required for combustion would have been considerably increased.

Every scheme should be studied on the lines indicated by the diagram, which would ensure a proper ratio of various heating surfaces, and, at the same time, keep down the capital expenditure.

Mr. T. Sugden.

Mr. T. Sugden said he understood Major Utting to suggest it was better to split up the gases they had got partially heated in the economiser, and finish heating them in an air heater. Could this be done under normal conditions, or did it entail introducing a special draught to take up the additional heat?

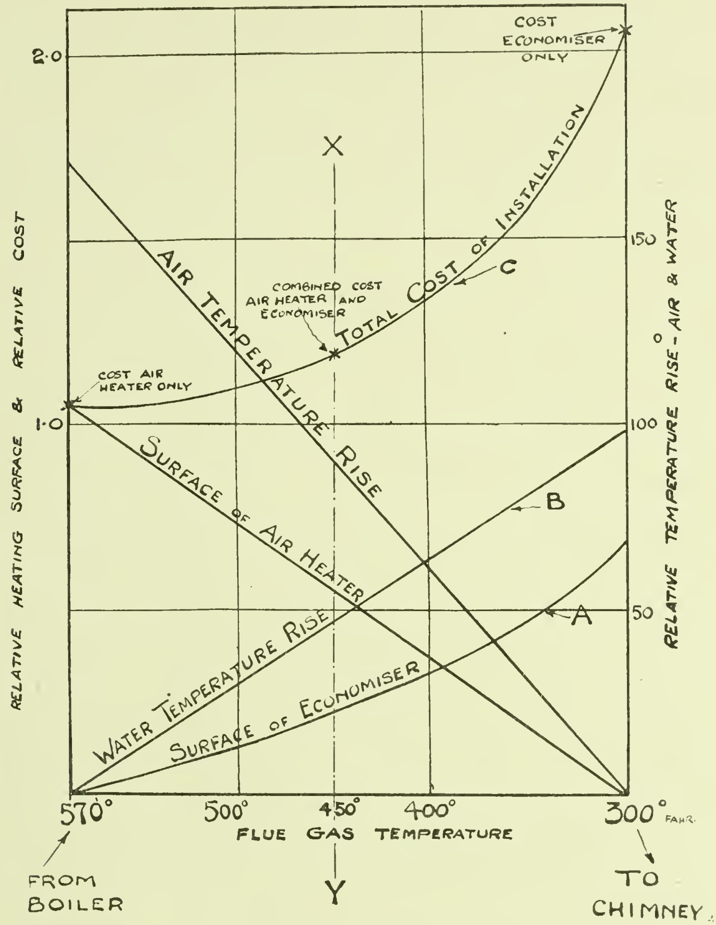
Major S. Utting.

Major Utting, continuing, said that in practically all modern installations, or, at least, in those in which it is desired to cool the chimney gases to 300° F., or less, mechanical draught was invariably employed. More draught would be required on account of the extra resistance in the flue gas circuit for the combination he proposed, but this resistance would be partly compensated for by the fact that the resistance of the fuel bed would be overcome by means of the forced draught fan supplying the heated air.

Mr. David Rushworth.

Mr. David Rushworth said he did not agree with Major Utting as to cast-iron economisers not being able to take present-day and future high pressures. His experience was that a cast-iron economiser could take pressures up to 300 lb. and over. It was an easy matter to deal with feed-water to the economiser by feeding the economiser on the inlet side with an ordinary Weir pump, and taking it out at the outlet by means

of a 2 or 3 stage turbine pump. His experience was that this method gave excellent results. With regard to air heaters, this idea to do away with economisers was beyond his comprehen- **Mr. David Rushworth.**



'Thermix' Air Heater.

sion. He could understand combining air heaters and economisers. ('That is what he said.' Laughter.) Well, he was so appalled he did not hear him. (Laughter.) Mr. Brownlie had spoken of rule-of-thumb methods. It was not the maker who was to blame; it was the buyer. (Laughter.) Offer an adequate

Mr. David Rushworth.

economiser to a would-be purchaser, and he said 'Oh, I cannot spend all that money on an economiser. I only want to heat water up to 212° F., because the water-tube boiler people say from and at 212°. (Laughter.) This, generally speaking, was why economisers were not put in equal to the full capacity. If economisers were proportioned to the amount of evaporation per hour of the boilers in lbs. of water, and the same given to the economiser, they got excellent results. As regards the life of economisers, he had known many that had not lasted more than five years, but it was entirely due to the fact that the people using them had not looked after them and fed them with cold water. As to the use of hard water, it could not be expected that a feed-water heater should also be a water purifier; it must be one thing or another. An economiser would throw down the matter held in suspension in the water, which should be blown off regularly, but never was. (Laughter.) He ventured to say there was not a blow-off valve on 90 per cent. of economisers that was opened from one week's end to another. Where the water used was hard, there was always a process of cleaning out with handy tools made for the purpose. As to the prejudice of colliery engineers against economisers, that was well known—(laughter)—but they were getting better educated. Mr. Brownlie stated that all the available exhaust steam should go to the feed-water heater, so as to heat the inlet water on the way to the economiser. He (Mr. Rushworth) said, give them a three-stage heater—the exhaust, the economiser, and the final heater in the boiler, like the Wilkinson type.

The President.

The PRESIDENT: Are you not going beyond the subject?

Mr. David Rushworth.

Mr. RUSHWORTH (continuing): There you get the perfect feed-water heating arrangement. (Laughter.)

Mr. J. P. O'Callaghan.

Mr. J. P. O'CALLAGHAN, F.C.S. (London), said in congratulating Mr. Brownlie on his masterly presentation of the case for more scientific management in the boiler house, might he

as a chemist with some experience of the problems arising out of the use of unsuitable feed-water, express a slight sense of disappointment that he had dealt almost exclusively with the purely mechanical aspects of the question, and had made only a passing reference to the vitally important subject of water treatment. All the various devices for the obtaining of an increased evaporation per lb. of coal, which had been so spiritedly described and debated that afternoon, presupposed for their full efficiency *a clean boiler*, that was, a boiler which was free from heat-resisting scale deposited by the feed-water. It was of very little use to gain 5 per cent. here and 10 per cent. there, if, owing to the use of a hard, scale-forming water, they were throwing away *in the boiler itself* 16 per cent. and upwards of the heating value of the coal. Perhaps at some future time Mr. Brownlie would devote some attention to this question. As far as he (the speaker) was aware, no really authentic figures had been given for the heat losses due to varying thicknesses of scale since Professor Rankine made his classic researches many years ago, and it was his (Mr. O'Callaghan's) conviction that the collection and publication of comparative data under this head would bring home to boiler-users the magnitude of the heat-loss due to the use of hard water, and the futility of instituting economies elsewhere in the steam system while the very boiler itself remained one of the greatest agents of waste, through the neglect to provide the first essential of economical steam raising, viz., a good water softener. **Mr. J. P. O'Callaghan.**

Mr. William Ball, Swansea, said they had heard a good deal about economisers and hot feed-water. **Mr. William Ball.**

His firm's injector would feed the boiler with exhaust steam alone at all pressures up to 120 lb. per square inch, and the water would deliver into the boiler at a temperature of 190° F. They had injectors of this type in South Wales which had been

Mr. William Ball.

running for over thirty years, and their injectors in that district delivered in the aggregate about $1\frac{1}{2}$ millions of water per hour. This type of injector was specially adapted for locomotives, and over 5,000 locomotives were at present fitted with exhaust steam injectors.

Major E. Ivor David.

Major E. Ivor David (Aberdare) stated that the large attendance at that meeting showed that the paper was the most interesting which had been submitted to the Institute for some time. During the recent coal stoppage many colliery engineers had occasion to look more closely into the condition of their boiler-house plant than they had ever done before, and as a result a general tendency to improve was noticeable. They could only conclude from the figures in the paper that Mr. Brownlie had been called in chiefly to view the bad cases and to advise; the good plants had evidently been overlooked. In the old days the principal load on the colliery boilers was the winder, which at one part of the wind would consume steam at the rate of 50,000 lb. per hour, and in the next 40 seconds would not be drawing steam at all, and the result was the Lancashire boiler, owing to its large water reserve, was considered the only boiler for colliery purposes. But with the advance in colliery engineering there were added to the winder compressors and a fan continually running, and also mixed pressure turbines using the exhaust steam from these or high pressure steam when the winder was not running. All these things had evened up the demand, and there was no necessity for Lancashire boilers for colliery equipment on modern lines. As an illustration he would give the case of an old-style colliery with one winder only and with three Lancashire boilers. The average demand over the week was 11,000 lb. of steam per hour, and over the shift 18,000 lb. The maximum demand of the winder was at the rate of 45,000 lb., and the boiler efficiency from 62 per cent. to 63 per cent. They were fired with a

mixture of small and peas. Next take the later style colliery, with two winders, continuous-running compressors, and mixed pressure turbines. The average demand over the week was 80,000 lb. of steam per hour, and over the shift 110,000 lb. The maximum demand of the two winders and one air compressor was at the rate of 190,000 lb., and the boiler efficiency was from 72 per cent. to 76 per cent., with washed duff coal. He should like to point out that South Wales was the pioneer of high-pressure and high-temperature plant in the world, installed as the result of the courage and initiative of a member of this Institute. (Applause.) The plant was now running using washed duff, worked at 350 lb. pressure, with 750° superheat, and during a recent test of a day's run the efficiency of the boilers was over 84 per cent. The boilers had induced draught, superheaters, economisers, and air heaters, and each boiler was a separate unit. Heated air at about 110° F. was supplied to these boilers during the test, but at present the additional air heater was not used because it was not considered necessary and the result would probably be too high temperatures in the furnaces. It was truly said that the colliery power house was the ' dump ' for all classes of coal. Any coal which the salesmen could not sell at the moment was used. With regard to feed-water heaters, he noticed in the ideal plant the temperature of the water entering the economiser was 95°. He thought such economisers would be included in the throng of economisers that wore out in five years. The temperature of the water in high-efficiency modern plants should be between 160° and 170°, which could be easily obtained by using all the available exhaust steam. Major E. Ivor David.

Mr. R. Clarke (London) said pumping through economisers and taking the water in at 250° was done some years ago; and he was in a position to confirm this. Mr. R. Clarke.

Mr. V. R. Chadwick (London) said there was no doubt Mr. V. R. Chadwick.

Mr. V. R. Chadwick.

the tests given by Mr. Brownlie represented what happened, and they must not judge exactly by what came under their own ken. But how many colliery plants in South Wales were up to date ?

The majority of them were hand-fired ; and after all they were considering average conditions, and not criticising the particular boiler plant of members of that Institute, which would naturally be expected to be working efficiently. The author made passing reference on page 432 to the balanced draught—a combination of forced and induced draught. This was an ideal combination. Say they had a thick bed of fire of Welsh coal—four or five inches—it wanted more draught to get air for combustion through the fire than it did to overcome the frictional losses in the flue ; and why trust to induced draught or chimney draught to do all that ? He thought Mr. Brownlie would agree with him that the correct system was to adopt means to force the air for combustion through the bed of fire, and after that let the chimney draught overcome the frictional loss of the gases from the flue and carry it away. He was at a colliery in the Midlands last week, where was installed a battery of six boilers, with induced draught, and a fairly short chimney—60 feet. He had always considered that the induced draught fan was worked too quickly, and it was run at half-speed. Fortunately, or unfortunately, the fan broke down at the time of his visit, and natural draught was resorted to. With the fan running half-speed there was 9 per cent. of CO_2 ; with natural draught, giving all the steam the colliery wanted, it averaged 12 per cent. Mr. Brownlie cited as one of the disadvantages of mechanical draught that ‘ forced draught has the slight objection that the blast has to be shut off (mechanically) every time the fire doors are opened, and a fairly high chimney is still necessary to take the gases away. Well, he had mentioned the case of the 60-foot chimney, with

six boilers, and the forced draught was never cut off, so that no cold air was going in. Then Mr. Brownlie said some form of mechanical draught was essential. If he had said 'forced draught,' he could agree with him. With regard to burning anthracite, it was fairly well known that anthracite duff would not burn, with any rough handling, in a mechanical stoker. It had to be on a fixed grate, and a fairly thin fire, and it was necessary in burning it to have forced draught, which must be a balanced draught, to prevent unconsumed fuel being carried into the flues. **Mr. V. R. Chadwick.**

Major S. Utting said that in order to remove any misapprehension with regard to the practice of heating air for combustion, he might say that it was long past the experimental stage. **Major S. Utting.**

In a new power station now building, heated air for combustion was provided for at the rate of over 1,500,000 cubic feet per minute, and that two of the 'Thermix' air heaters each had over 18,800 sq. ft. surface.

He would also add, for Mr. Rushworth's peace of mind, that there were economisers in the scheme, and that the heaters were placed *after* the economisers.

Mr. Evans had quoted Bristol electricity figures, and had stated that the power absorbed by the forced draught plant amounted to from one-third to one-half per cent. of the boiler output. He used these figures apparently to show that forced draught and a short natural draught chimney was the ideal method, from the point of view of low energy, for the mechanical draught equipment, and looked forward to the day when such would be the standard arrangement. Further, he considered it sufficient to ensure a *balanced* draught system. In giving us these figures Mr. Evans had omitted all reference to the other side of the Bristol draught installation—that is, the induced draught side, which performed the greater part of the work.

Major S. Utting.

To that he gave no credit whatever; but if they agreed that the evaporation, and therefore the combustion, was or could be obtained with the total expenditure of power stated, then Mr. Evans had made two very important statements; namely, they were a long way out in their estimates of the total draught requirements to have installed induced draught fans and motors which were found to be unnecessary, and that the resistance of the flue gas circuit, including boiler, economiser, flues, etc., did not exceed 0·25 inch—*i.e.*, the draught corresponding to a chimney about 60 feet high, with flue gases at, say, 325° F.

The speaker had installed six large sets of induced draught plant on a modern boiler plant at an electricity works. Another contractor had installed forced draught fans for the same boilers, and it could neither be considered honest nor correct if he stated that 15,000 lb. of coal per hour were to be burnt for a consumption of 54 B.H.P., *i.e.*, the total load on the induced draught end, and ignored the part played by the contractor for the forced draught, who, at least, expected some credit for his share in the operation.

Unless the Bristol induced draught plant was admittedly unnecessary, Mr. Evans had not done this. The speaker considered that, so far as it concerned the average modern boiler installation, Mr. Evans' balanced draught proposal was a delusion, and, as he indicated by blackboard diagrams, could only result in excessive positive pressure in the combustion chamber, and even at a point back towards the boiler damper.

Mr. Chadwick apparently considered a natural draught chimney good enough. Certainly, in the author's table (page 413, col. 4), they might expect to obtain all the required draught in this way, but at what cost?

Consider the energy going to waste *via* the chimney with gases at 660° to 690° F. The author had stated on page 432

that chimney draught could be used successfully with a chimney high enough to give 1 inch w.g. with flue gases at 325° F. **Major S. Utting.**

The speaker entirely agreed with this statement, but pointed out that it would mean a chimney about 300 feet high. Consequently, he was somewhat puzzled by the author's draught figure of 1·75 inches with gases at 310° F.—see col. 5, page 413.

Perhaps col. 3, page 419, would throw some light on this point. There the author gives as representative of 'Good Plant' 2 inches w.g. at the *chimney base* or *fan inlet*, which were not the same thing. Draught value at the fan *inlet* was a misleading figure, and ought never to be quoted. This was evident when it could be shown (as indicated on the blackboard) that, with the boiler on maximum duty, the w.g. reading might be 2 inches and on light load $2\frac{1}{2}$ inches, although the draught at the boiler damper and economiser outlet had been reduced as might be expected.

In the author's 'Modern Plant run on Scientific Lines,' page 413, column 5, the feed inlet temperature to economiser required some explanation. In all the other examples, good, bad, and indifferent, the temperature was higher. The economiser efficiency, 14·16 per cent., apparently confirms that it is not an error. He surely did not propose cooling the available feed-water for the satisfaction of obtaining a high economiser efficiency, especially after his warning *re* the bad effect of cold feed on the economiser tubes.

Mr. WHITTAKER, junior, stated, with regard to the question of draught in general, that many engineers imagined that their boilers had not the requisite amount of air for combustion, whereas the direct opposite was generally the case. To put the whole thing in a nutshell, if the fires were maintained in clean condition the whole of the shift (and this could only be accomplished mechanically), the exact amount of air required for combustion could be regulated exactly according to the **Mr. Whittaker.**

Mr. Whittaker.

load on the boiler. There were mechanical grates which did this quite satisfactorily and without excessive up-keep. As to the value of recording instruments in the boiler house, 'Where ignorance is bliss, 'tis folly to be wise' was not always a safe rule to follow; at least it would not apply to steam-raising plants where the engineer and his staff wanted to help to produce waste and loss. A recording instrument was a witness of the work being done by some particular machine, and it played an important part in locating waste and loss.

There was an amusing story about a nigger under trial for chicken stealing. The Judge took a hand after closing of all testimony on the part of the Crown, and asked the man if he had witnesses, to which the black man replied: 'Judge, I expect I'm a little peculiar—when I goes out for chickens I never take no witnesses.' He (Mr. Whittaker) was afraid there were many engineers who did not want any witnesses. Who would purchase a high-grade motor-car with no instrument board and no instruments? Suppose the salesman argued that the machine would run just as well without instruments, and that they were a useless expense, such a salesman would never make a sale because nobody with any common sense would buy a car without a complete instrument equipment. In the Chief Engineer's office of large modern passenger steamships were complete instrument boards showing the working of all machinery and equipment. No passenger steamers would be permitted to run without such instruments. Too many steam-raising plants were working in the dark without complete sets of recording instruments. It was of vital importance to the successful engineer to have the boiler house equipped with recording instruments, the intelligent use of which would help to reduce waste and loss. Thus the boiler house instrument board gave a very interesting guide and clue as to the overall efficiency of the boilers.

Mr. Algar W. Bell (Newport) said, as to the problem of getting sufficient air to make up the proportions of combustion, he believed the accepted figure for the amount of air which could be passed through the grate of the ordinary furnace was about 7 to 10 to 1 of coal. It was possible to put the remaining 7 parts of air over the fuel bed. The essence of the whole thing was to get the gases as they rose from the fuel bed; it was no use getting them later on. Mr. Algar W. Bell.

The President: Can you tell us how to do it? The President.

Mr. Bell said it could be done by putting in a small spray of decomposed steam to carry air oxygen from the ash-pit, forcing it against the flow of the draught. This had been done in many places with a considerable degree of success. Mr. Bell.

Mr. O'Connor said one of the difficulties he found in adopting mechanical forced draught was that, when the pressure above the fire was in excess, there was an element of danger when a man had to open the doors of the furnace, as this immediately resulted in the shooting out of a jet of flame. Mr. O'Connor.

It was this liability which induced him to adopt the idea of reducing as much as possible the 'drag' on the gases on their way out to the atmosphere from the furnace, and it was wonderful how little depression was necessary in order to carry the flue-gases away—the more so if the last downward pass was abolished and the gases allowed to pass upward to the chimney. He had a boiler of 24,000 lb. hourly evaporation, with a chimney only 50 feet high, yet the inspection doors in the furnace could be opened at any moment, and there was just a slight inflow, which showed that the draught was really balanced. While the induced method was attractive because of the convenience with which it could be applied—the much smaller amount of air moved by the forced draught method appeared to be the more economical, and if fitted with the comparatively

Mr. O'Connor. low chimney necessary to produce a balance over the fire, he thought the arrangement would be found to be preferable under most conditions.

Mr. J. R. Chalmers. Mr. J. R. Chalmers said the balanced draught was the best that could be installed to obtain the finest results with the lowest grade fuel. Most of the anthracite fuels must have forced draught. As regarded height of chimney, even 50 feet was not required with an induced or balanced draught system. He had known chimneys only 20 feet high where induced draught was adopted. Mr. Brownlie stated, among the disadvantages of mechanical draught, that it took from 2 to $2\frac{1}{2}$ per cent. of the steam production of the plant to work the fan. He (Mr. Chalmers) presumed that this figure was given as an average, because he had induced draught plants running at about 1 per cent., balanced draught $1\frac{1}{2}$ per cent., and forced draught rather less than 1 per cent. He did not think all the credit should be given to the forced draught in the installation mentioned by the previous speaker, but that the induced draught portion of this balanced draught plant should have due consideration.

Professor Frederic Bacon. Professor Frederic Bacon (Swansea) said he was glad Mr. Brownlie had found it possible, in such a crowded paper, to refer to the subject of lagging steam pipes. A 4-inch pipe, 50 feet long, left bare, would condense about 40 lb. of steam per hour, whereas 90 per cent. of that could be saved if the pipe was effectively lagged. The author stated: 'only high-class coverings—magnesia, slag wool, or diatomite, with a high percentage of asbestos—should be used.' He (the Professor) was commissioned by the Admiralty to conduct experiments upon the properties of heat insulators, and he found that asbestos was far from being a good heat insulator. He would therefore question whether a high percentage of asbestos was really a criterion to a good heat insulator. He was on the

teaching side of engineering, and experienced difficulty in inducing students to take a full course. Mr. Brownlie asked that boiler plant should have a skilled attendant. He (the Professor) surmised this skilled man would be expected to do the work on a salary of £350 a year—rather less than a good stoker earned. Was it worth a man's while to go to college for such remuneration? It was agreed that the man who handled the equivalent of a shovel must be better paid. By the employment of such a man half their boiler house troubles would disappear. Mr. Brownlie said we were no worse than the average in other countries. This was comforting, because he (the Professor) would have thought we were. He should have thought the United Kingdom was a good deal worse in these matters. They must bear in mind that Germany had an output last year of 110,000,000 tons of lignite, which was the cheapest possible coal, even allowing for its inferior thermal value. **Professor Frederic Bacon.**

Since 1916 France had got 850,000 water h.p. at work; Switzerland 600,000 water h.p.; Spain 500,000 water h.p.; Italy 2,000,000 water h.p.; and the United States 10,000,000 water h.p., out of an available 28,000,000 water h.p. These figures should set us thinking, and induce us to conserve what little coal we had got, which was only $2\frac{1}{2}$ per cent. of the world's store.

Mr. S. B. Haslam said he had been extremely interested in Mr. Brownlie's paper, and would like to offer his congratulations, not only on his courage in tackling such a huge question in a paper, but also on the very excellent way in which he had carried out the work. No doubt, Mr. Brownlie would have preferred to take very much more time over his subject, just as he would like to have more than ten minutes to discuss it. As time was limited, he would confine himself to one part of boiler house management which was of necessity **Mr. S. B. Haslam.**

Mr. S. B. Haslam.

touched on very lightly, and that was the composition of the flue gases. If they took Mr. Brownlie's own figures on 250 boiler plants typical of all industries, and 100 colliery boiler plants, they found that the average consumption of coal was about 770 lb. per hour per boiler, or one ton in three hours. Let them keep this figure of three hours before them, and consider what took place when coal was burnt. When 1 lb. of pure carbon was completely burnt in oxygen, it formed CO_2, and produced 14,650 B.Th.U., whereas the same weight of carbon burnt to CO only yielded 4,450 B.Th.U., a loss of 10,200 B.Th.U. The same losses, of course, occurred in the same proportion, though in a smaller quantity, when 1 lb. of coal was burnt in air. It was necessary, of course, to have an excess of air in order to complete combustion, owing to the fact that the process of combustion was so extremely rapid that without excess air a considerable amount of free carbon would get away in the gases; but while it was necessary to have a certain proportion of excess air, it must be borne in mind that too much excess air was as bad for economy as too little. It was impossible to deal now with the various chemical changes taking place during combustion, but he might, perhaps, refer anyone interested to the paper he read before this Institute on February 16, 1910.

Put briefly, it would be found that with an average coal containing 86 per cent. of carbon burnt in a sufficient amount of air to give 40per cent. excess oxygen, a percentage of CO_2 equivalent to 13 per cent. of the total permanent flue gas should be obtained. Theoretically, this was not good enough, and would mean an actual loss of 14 per cent. of the total B.Th.U. available were that coal burnt to the best possible theoretical advantage, but, as they all knew, the best possible theoretical advantage was not by any means always the best practical advantage, and it might be assumed that, from a practical point of view,

13 per cent. of CO_2 was what should be aimed at. This gave a loss in heat units of 14 per cent. **Mr. S. B. Haslam.**

With	12 per cent.	CO_2	this loss is	15	per cent.
,,	11	,,	,,	16	,,
,,	10	,,	,,	18	,,
,,	9	,,	,,	20	,,
,,	8	,,	,,	23	,,
,,	7	,,	,,	26	,,
,,	6	,,	,,	30	,,
,,	5	,,	,,	36	,,

and he would not mind having a quiet bet that a good many boilers in this district were working with only 5 per cent. CO_2 in their flue gases.

Let them just take the figures from Mr. Brownlie's test. Here the average percentage of CO_2 over the 350 plants mentioned was just over the 7·5 per cent., or a loss of practically 25 per cent. of the total available heat units. In other words, had the coal been burnt to the best possible advantage, the one ton which was now used in three hours would have kept up the same evaporation for four hours. Although this result was too much to expect, there was no reason at all why proper attention to various points should not keep up that evaporation to $3\frac{1}{2}$ hours per boiler per ton of fuel. The resultant economy on a plant of several boilers working on full pressure for from eight to twenty-four hours a day was enormous.

The previous speaker had referred to the human element and to the necessity of training and controlling this. He quite agreed; and would suggest that quite the best means of control lay in a CO_2 recorder, especially when used in conjunction with draught gauges. There were many points which should be attended to in order to improve the CO_2 record, and in enumerating some of these, he would like to call their

Mr. S. B. Haslam.

attention to the fact that over 80 per cent. depend on the human element, and the record would act as a check on the inefficient stoker. (He might, perhaps, be allowed to mention here that he had no interest whatever in the sale of a CO_2 recorder or draught gauge):

(1) The brickwork of a boiler setting and flues, leaks being a very constant cause of losses.
(2) Thickness of the fires. The thicker the fire, provided it is even, the better, as then the chemical combination of carbon and oxygen has a better chance.
(3) The adjustment of the dampers to give the right amount of air, including the necessary 40 per cent. excess.
(4) Careless firing resulting in unequal fires.
(5) Slackness in raking and cleaning, resulting in heavy clinker in some parts of the fire and holes in other parts, causing unequal distribution of the air and oxygen.
(6) Injudicious cleaning, the results of which are seen in the enormous amount of unconsumed carbon in the ash.

Mr. J. E. Lea.

Mr. J. E. Lea (Manchester) stated that the first step towards coal economy was 'measurement,' and measurement was the sum total of Mr. Brownlie's paper.

Boilers—whether Lancashire, water-tube, or marine—were all fundamentally the same in construction, and when treated properly and under good conditions they would all give practically the same efficiency. He quite agreed with Mr. Brownlie that the chief cause of waste in connection with boilers was lack of proper attention. Throughout the country boilers of first class or A1 construction received only C3 maintenance. The 'point of view,' or way in which boilers were regarded, was a most important matter. Boilers were

not machines like engines or steam turbines, and they called for far greater skill in attending to them. Boilers were organisms. The efficiency of an engine or steam turbine chiefly depended upon its design and construction. The efficiency of a boiler depended mainly upon its maintenance and upon the care and attention devoted to it. They had heard a good deal in the discussion about the 'human element.' A boiler was as much like a human being, or animal, as anything could be. All animals consumed carbon and air, but they required them in the proper proportions. The same with boilers. Like individuals, they suffered greatly from indigestion. (Laughter.) What was the CO_2 recorder for? It was simply an indicator as to the state of the digestion. Boilers suffered also from bad circulation—(laughter)—from chills, impure water, and derangement of their internal organs. The boiler was an object of living interest, and Mr. Brownlie was our chief medical adviser. (Laughter.) That gentleman was doing a great public service, in arousing the country to the immense waste of coal that was going on unnecessarily, and he deserved our best thanks. (Applause.) **Mr. J. E. Lea.**

Mr. C. REYNOLDS SAMS (London) stated that the reduction in miners' wages from November 1 to 28·95 per cent. above the 1915 standard had placed the position in the coalfield on a very delicate basis. As the *Financial Times* had pointed out, it brought the Welsh miners very close to the minimum wages, and as the men would now earn from 8*s.* 10½*d.* per day in the case of the collier down to 6*s.* 5½*d.* per day in the case of the labourer, representing little more than one-third of the wages of last January, it was obvious that the working men of the Welsh coalfield were in sore straits. Their position was rendered all the worse when the pits work only three or four days per week. **Mr. C. Reynolds Sams.**

The coal-owners recognised that they could not very well

Mr. C. Reynolds Sams. ask the miners to accept still lower wages, and that they must get costs reduced in other ways. An important reduction of costs could be brought about by reducing or preventing waste, and that could only be done by knowing where that waste was, and combating it by the introduction and use of the various instruments now to be obtained, such as CO_2 recorders, draught gauges, pyrometers, steam-meters, water-meters, and other apparatus. By installing meters, actual quantities were recorded, and the engineer could determine whether everything was being usefully employed; if not, he could begin to make his economies. The cost of installing these instruments was often paid for in a few months by economies effected. In one case which was within his knowledge, the sum of £300 was spent on instruments and 1,900 tons of coal were saved in one year. And in another case, after the meter was introduced, three boilers were found to be able to do the work where four boilers had been necessary. He knew many engineers who wanted these instruments brought into use, but their directors would not find the money for them. It was unfortunate that this part of the discussion had come so late, when the gentlemen who looked like directors had left the meeting. (Laughter.)

Mr. C. E. Foster. Mr. C. E. Foster (Letchworth) said he did not think there was any information in the paper as to the actual temperature in the combustion chamber. The first they heard about temperatures in figures occurred after all the mischief was done, namely, somewhere near the economiser. One speaker in the discussion certainly mentioned 2,000° C. of temperature in the combustion chamber, but he (Mr. Foster) believed that that figure was one which was attended by results not desirable to repeat. He strongly urged that measurement of temperature in and about combustion chambers should be made, and much more generally studied than was the case at present. It was the starting point of the temperature processes in the boiler,

yet there was usually a 'conspiracy of silence' on this subject when engineers discussed boiler performances. Mr. C. E. Foster.

Mr. NORMAN HOPE (Neath) said the pump was the weak spot in a steam plant. On page 435 the author referred to the several types of pumps. Could he give them the respective efficiencies of these pumps? For reliability, nothing beat the direct-acting Weir pump, and Mr. Brownlie had taken the common-sense view that in order to secure reliability even efficiency might be sacrificed. Wherever they went they saw exhaust steam blowing off. Why should that be when, for a few hundred pounds, a good surface condensing plant could be obtained which would obviate it? Mr. Norman Hope.

Mr. G. TUCKER JONES (Hengoed) said they had heard much about low-grade and refuse fuel. In his opinion this class of coal should be treated as commercial coal; slack and all 'foreign' matter should be taken out, and the residue bunkered and eventually passed on in a proper condition to the stokehole. Mr. G. Tucker Jones.

Major E. IVOR DAVID said Mr. Brownlie's paper gave a most interesting series of tabulated tests, but it was impossible for engineers to compare the results which they were obtaining with these unless the conditions of loading of these particular boilers were given. The discussion had not brought out much information. Colliery engineers present would like to have heard something more than extracts from various manufacturers' catalogues. Personal experience of various accessories, either successful or unsuccessful, were of more value. In connection with water-tube boilers there is sufficient information amongst South Wales engineers which, if collected, would enable various details to be standardised. Thus, the length of arches to be used for burning various classes of fuel, the relation of grate to boiler area, the ratio of economiser and superheat areas, and the draught water gauges for various thicknesses of fire and Major E. Ivor David.

Major E. Ivor David. classes of fuel, could all be fixed if information were interchanged freely.

As an example of the benefits of boiler house management he would give an instance of a colliery power station, supplying a colliery load, which originally consumed 2·6 lb. of coal per unit generated. This was reduced in twelve months to 1·96 lb. of coal per unit generated by attention to the essential details of boiler house management. Measuring instruments were first installed, or those available corrected. These comprised accurate draught gauges, CO_2 recorders, recording water meters, and steam temperature recorder. The temperature reading in the furnaces and flues proved that the economisers were too small. These were doubled in size. The CO_2 was very low. This was traced to air leaks in the brickwork, underloading of the boilers, incorrect shape of the combustion chamber, and incorrect thickness of fires due to the entrance gate of the chain grate stokers not being straight, with the result that the indicator bore no relation to the true thickness of the fire. These defects were corrected as follows: The brickwork was searched for air leaks, which were stopped, and the whole surface of the boilers tarred. The number of boilers was reduced until they were running at 80 to 90 per cent. of their normal rating, the arches were lengthened until combustion took place within a foot of the dead plate, the coal gates were straightened and the indicators corrected. The draught control was improved and a relation fixed between draught and thickness of fire, with results given above and a reduction of 30 per cent. in coal consumption, and at the same time the quality of the coal used has been reduced. Very little improvement can be made in the efficiency of boilers without reliable measuring apparatus, and in a new boiler installation with which he was concerned it was proposed to have an instrument board upon which would be mounted a

steam pressure recorder, steam temperature recorder, steam flow recorder, CO_2 recorder, and two draught gauges giving pressure above and below the fire, also a wheel for the regulation of the draught. The only other things to be regulated were the thickness of fire and the feed. Major E. Ivor David.

Mr. ARTHUR GROUNDS (Manchester) said it was not always safe to act on the CO_2 of flue gases only, because with high temperatures they might be getting percentages of carbon monoxide which might lead to the waste of a great deal of heat. As to Professor Bacon's remarks on lagging, the material commonly used in America was 80 per cent. magnesia, an inorganic material. Most organic lagging materials shrunk from the pipes at a high degree of super-heat. Another point was, CO_2 recorders were liable to go wrong, and should be checked regularly. With regard to the percentage of combustible matter in the ash, that was a chemist's job ; and another chemist's job was the question of water-softening. Mr. Arthur Grounds.

Mr. W. H. REYNOLDS wrote :—*Section* 1.—I fully agree with the author's remarks as to the necessity for efficient design and equipment of boiler plants, also the skilled control of such plants. Mr. W. H. Reynolds.

The statistics quoted by Mr. Brownlie relating to the enormous wastage of fuel due to imperfect and out-of-date plants, as well as the crude supervision given to many steam-raising plants, confirm the information published by the Technical Department of the Coal Control Board, which, by the way, had the advantage of the services of an expert who had previously specialised for many years in connection with the scientific combustion of fuel and the operation of boiler plants. Further, the Department had a large body of recognised engineers throughout the country specially engaged upon the fuel economy campaign which the war made imperative. The utmost economy in the use of fuel is just as important now as

Mr. W. H. Reynolds.

it was during the war; possibly more so, because, in view of foreign competition, etc., cheapness of production is most vital to this country. We are much indebted, therefore, to Mr. Brownlie for bringing the question home to us.

Although the position is undoubtedly bad, I do not agree that there has been wholesale neglect. The paper states that hitherto there has not been much data available as to the results obtained in practice in boiler houses. I would point out that there are very complete statistics available relative to the electric power houses of this country, whose total coal consumption amounts to about 7,500,000 tons per annum.

The bulk of the statistics given in the paper appear to be in connection with the Lancashire type of boiler, and although Mr. Brownlie states further on that, so far as the best type of boiler is concerned, it is a question of the Lancashire *v.* the water-tube, it does not appear possible to me to arrive at a definite comparison by using the information given in the paper.

I do not wish to laud up the merits of water-tube boilers here because, as the majority of the Members of the Institute know, I am specially interested in a very well known water-tube boiler, and my views would probably be considered biassed in consequence. I should much prefer the owners and users of water-tube boilers to give their own actual experiences; doubtless there are many present who have both Lancashire and water-tube boilers under their care. I venture to suggest that their views would be of special value and interest, and I hope they will give them.

I will simply say that the very large number of water-tube boilers now in use, and the fact that practically all the most modern power plants in commission, or under construction, to-day are equipped with the water-tube type, is a clear indication that where maximum efficiency and cheapness of running

and maintenance costs are desired, mechanically fired large water-tube units are essential. Mr. W. H. Reynolds.

As Mr. Brownlie points out, an official census of the steam-raising plants of the country is badly needed, but the proportions of water-tube as compared with Lancashire boilers put forward by Mr. Brownlie are, I think, not quite correct. I believe it is safe to say that in actual number of boilers at work, the Lancashire is little, if anything, over 50 per cent. of the total, while from an evaporation point of view, it must be obvious that whereas the normal capacity of a 30 feet × 8 feet Lancashire boiler is about 6,000 to 7,000 lb. of steam per hour, the average capacity of the water-tube boilers in use throughout the country is much higher—in many cases three or four times as much. Therefore the total duty provided by the water-tube must be much greater than that of the Lancashire.

On the question of efficiency, I note Mr. Brownlie has found that the average of what are apparently up-to-date water-tube boiler plants, properly equipped, is 9 per cent. better than the Lancashire. This is a considerable saving in itself, and to-day a most important item. There is no doubt in my mind that the water-tube is more efficient, because the temperature of the waste gases leaving the boiler (not at the base of the stack) averages about 475–500° F., whereas the temperature of the gases leaving the Lancashire boiler is at least 650° F., and very often higher. This means that to obtain an equivalent overall efficiency much larger economisers are necessary with the Lancashire than with the water-tube.

Section 2.—I do not agree with the opening remarks of this section of the paper, to the effect that for water-tube boilers mechanical stoking is essential. The small sizes can be just as efficiently hand fired as the Shell type, and there are water-tube boilers in this country having evaporative capacities as high as 20,000 lb. per hour which are hand fired. I under-

Mr. W. H. Reynolds.

stand their furnace efficiency is quite as good as that of any Lancashire boiler hand fired furnace.

Mr. Brownlie seems to be undecided as to the relative merits of mechanical and hand firing. After nearly 13 years experience in South Wales, there is no doubt at all in my mind that mechanical firing is superior, especially for the larger sizes of water-tube boilers. I do not speak now for Lancashire boilers at all in this particular connection, except to say that the water-tube boiler with its comparatively large refractory furnace is much better suited to mechanical furnaces than the comparatively small steel furnaces of the Lancashire boiler. I believe this applies especially to the coals of this district.

The successful introduction to this district, after fairly exhaustive experiments, of a suitable mechanical stoker for water-tube boilers, made the large number of big capacity boilers now installed in South Wales feasible. Further, in conjunction with suitable coal and ash handling appliances, it means a big reduction in labour, as many as 24 to 30 men per shift being dispensed with in some cases.

The efficiency of the plants converted from hand to mechanical firing is not only improved, but is more uniform throughout the twenty-four hours. Inferior coals to those used when the boilers were hand fired are being used now on the mechanical grates, that is, coal having a bigger ash content, and therefore lower in calorific value.

That the steaming capacity of the plant is improved by mechanical firing, and that the plants are equally as flexible as when hand fired, is borne out by the fact that in many cases where the load is not less than formerly, and sometimes greater, fewer boilers are required to meet the steam demands. In the case of collieries another advantage is the immunity from serious losses underground under strike conditions, it being possible to maintain sufficient steam for pumping, ventilating,

etc., under such conditions more easily than when the boilers are hand fired. **Mr. W. H. Reynolds.**

Sections 3, 4, 5, *and* 6.—I agree generally with the author's statements under the various headings, and am convinced that proper care in the design, lay-out, and complete equipment of boiler plants with up-to-date appliances, instruments, etc., as well as proper supervision by a thoroughly competent and trained staff, are essential and necessary if we are to maintain our place in the world.

Mr. Brooker. Mr. Brooker wrote: I should like to congratulate the author on a very interesting paper, which should be of great value, and will be if it succeeds in convincing only a few engineers, managers, and other interested persons that there is more money to be saved in the boiler house than in any other section of an industrial plant.

I was not surprised by the figures showing that collieries are generally working at a very low boiler efficiency, as during the past two years I have visited a great number and have been astonished at the lack of interest shown in the question of efficient boiler operation. The general view seemed to be that coal was cheap and there was no point in saving it. This is, of course, a very short-sighted policy, especially at the present time when everyone is crying out for cheaper coal.

Some short time ago, working quite independently and with very little data, so that I had to guess a good deal, I estimated that the annual waste of coal in Great Britain was about 25 million tons. Everyone to whom I submitted my figures scoffed at me, and said they were ridiculous. Certainly they were rather high, but I am pleased to find them practically confirmed by so well known an authority as the author of this paper.

I agree that a boiler plant should be considered as a factory producing steam for sale, and that a proper system of costing

Mr. Brooker. is necessary. For the preparation of a balance sheet it is, I think, most convenient to reckon in 'heat units.' To do this, it is very necessary that sufficient water and steam meters and other instruments should be used. The heat units in the fuel can be very easily ascertained, and by measuring the steam output, all steam used by auxiliaries, and any exhaust steam used for feed-water heating, a very accurate heat balance can be obtained.

The importance of measuring the steam output of individual boilers is not yet thoroughly recognised. In most plants the total feed water to all boilers is measured by one meter. This is all very well, but unless the output of each boiler is measured by a reliable steam meter, you may have some boilers overloaded and others producing practically no steam. I have often been criticised for making this statement, but I know from experience that it is true.

As an instance, my firm recently supplied five steam meters for measuring the output of five boilers. On connecting up they showed three boilers at practically full load, and two at less than one-tenth full load. The engineer immediately condemned the meters, but after some trouble I persuaded him to take off the two 'loafing' boilers. The other three carried on comfortably. This happened at what was supposed to be a well-managed plant.

Another point, and one which I think the author could have brought out, is that by using steam and water meters the plant is practically running continuously under test conditions.

The figures given regarding the number of plants with no steam or water meters certainly surprised me, and I think they are rather over-estimated. I don't know how many boiler plants there are in this country, but if we assume the number is 20,000, that means that only 200 plants are using steam

meters. My firm alone have supplied steam meters to far more plants than that, and there are six other makes of steam meters in use. Mr. Brooker.

I should think the number of steam plants with no steam meters is nearer 90 per cent. of the total. However, the actual percentage is not vital. The point to be emphasised is that the number of plants without them is enormous, and that consequently there is still a lot of educational work to be done by authorities like Mr. Brownlie, and in a lesser way by the makers of steam and water meters.

Dr. S. Wolff wrote : At the outset of my remarks on this subject, I would like to make the general statement that whatever type of boiler comes under consideration, mechanical firing beats hand firing on practically every point. It is a fundamental fact that no human effort can keep up with a properly constructed machine working under the right conditions. Dr. S. Wolff.

As the greater percentage of boilers in this country, including South Wales, are Lancashire boilers, I will restrict myself entirely to mechanical stoking on this class of boiler.

Mr. Brownlie's average figures leave the impression on any one who reads his paper that, taking it all round, mechanical firing has practically no advantage over hand firing, although at the end of this part of his paper he gives the advantage to mechanical firing.

Suppose, for argument's sake, a doctor gives every one of his many patients, whatever illness they may complain of, the same medicine. What would be the result ? A certain percentage would regain their vitality, the rest would go from bad to worse by this prescription.

It is the same with Mr. Brownlie's statement regarding mechanically fired boiler plants on page 420 of his paper, viz., that mechanically fired boiler plants are actually giving inferior

Dr. S. Wolff. results to hand fired ones. This is no criterion at all for a subject like mechanical firing. Each boiler plant has to be studied by itself in order to form a true opinion on mechanical stoking. Averages do not give a true representation of what is the performance of a first-class machine stoker under good conditions. There are certainly many cases where the boiler plants are in such a poor state that the installation of machine stokers is a farce, and where the attention given to the machines is so wretched that it would be better to leave them alone till the machines are dropping off, and go back to more primitive methods.

Amount of steam produced.—It is most misleading with a subject like mechanical stoking to state that the average figure for 80 mechanically fired plants was 6,000 lb. evaporation per boiler per hour.

Each boiler plant has to be considered on its own. If a properly constructed machine stoker could do no more than the above evaporation on a well-managed Lancashire boiler plant, there would never be an inducement for steam users to consider the installation of machine stokers to increase the steam output, and thus save them the buying of one or two new boilers.

The crux of the whole matter is that the right type of stoker is not chosen for the purpose, and the boiler house conditions are so poor that the machine stoker has scarcely a chance of justifying itself. This is the reason that Mr. Brownlie arrives at 6,000 lb. evaporation per boiler per hour.

Flexibility in quality of fuel used.—In contradiction to Mr. Brownlie's statement that the application of machine stoking to colliery boiler plants is difficult, etc. (page 423), I have come to the conclusion, and especially with reference to South Wales, that the collieries are the ideal places for mechanical stoking. In well-managed collieries practically the same class of fuel is

always reserved for the boilers. I find that the fuel used there is more uniform than in any other industrial undertaking, and the reason that mechanical stokers have been scrapped at collieries is that they have not been properly looked after, or that they are worn out after many years' service. I agree with Mr. Brownlie that many colliery boiler plants are exposed to all weathers, and consequently everything suffers because the working conditions are against efficiency of every kind. **Dr. S. Wolff.**

It is appalling to me to find at the collieries Lancashire boiler plants where there is nothing to show that the slightest interest is taken in the scientific process of combustion. Ten yards away from the muddy boiler plant there is a nice building, the power house, with a mat on the doorstep carrying the inscription 'Please wipe your feet.' The time will soon arrive when this mat will be at the entrance of the boiler house, where the efficiency of the whole undertaking starts. It is in these kind of muddy desolate boiler sheds that mechanical stokers never will be a permanent success, and it would be a better policy to refuse to put a first-class machine stoker on where the boiler house conditions are, from the beginning, against the success of any kind of appliance, and to advise the people to put the boiler plant in proper order first.

Amount of fuel burnt.—Mr. Brownlie's statement, that in averages mechanical stokers are burning slightly more per boiler than with hand firing, but with little difference, is again very misleading, and requires a further explanation.

In other words, the only advantage in practice would mean that greater efficiency might be obtained, *i.e.*, more water might be evaporated per pound of coal.

It is the secret of machine stoking to burn within a certain time, if required, more coal as compared with hand firing, and to burn that coal more efficiently at the same time.

In South Wales, *e.g.*, people want more steam from the

Dr. S. Wolff. existing boiler plant; they want to burn more coal to get this greater output, but they cannot possibly do so by hand firing over any length of time, because the firemen cannot manage it under the best of boiler house conditions.

I am forced to the conclusion that the greater part of machine fired boiler plants which Mr. Brownlie has examined were never suitable to have an efficient machine stoker on, or that the attention given to the machines was so poor that the boilers would be better without them.

Cost of upkeep.—This is entirely a question of attention. Take a first-class motor-car as an example. If a pin or screw is worn, no time is lost in replacing these; the same should be done with machine stokers. On a battery of boilers it pays to have a mechanic who is responsible for the maintenance of the machines. One or two chauffeurs with mechanical knowledge to look after a first-class motor-car, and no mechanic to concentrate on a battery of machine stokers is ridiculous.

I recommend the training of an ex-soldier or sailor for the job, and you will be agreeably surprised at the result.

Cost of labour.—I cannot agree with Mr. Brownlie that, as a general rule, labour can only be saved when the plant is over four boilers. My experience is that on four hand-fired boilers two men per shift are usually employed; on machine fired boilers, one boiler can usually be out and one man looks after three boilers, thus saving three men per 24 hours.

Mr. J. W. Thornley. Mr. J. W. THORNLEY (Bolton) wrote: Under the heading of auxiliary plant, a great advance can be made in boiler efficiency and fuel saving. A vexing problem for a long time past has been the short-circuiting of the hot gases from the downtake chamber of Lancashire boilers, and it is only just being realised that, to prevent this waste, you must instal something automatic or self-acting—in short, an automatic expansion joint, in order to make your downtake chamber gas-tight.

In order to get an idea of the heat which is being wasted here, a simple test can be made on these lines. Make a test of your gases in the side flue immediately in front of your damper, and another test in the side flue as near the front of the boiler as you can get. By this means, you will probably find that your readings at the side damper are from 100° F. to 200° F. higher than the readings at the front end. You will admit these figures are remarkable, and readily see there is a decided need for improvement in this quarter, because, if these gases were doing their proper work, these readings should be reversed. Another point which cannot be emphasised too much is the fact that once the joints are installed, your walls are always intact, as the boiler never touches the brickwork, but is always in contact with the joint, thus saving the labour of continually rebuilding the brickwork. An average saving of 5 per cent. in coal consumption is being shown on boilers where installations have been made during the past three years. **Mr. J. W. Thornley.**

Superheated Steam.

Mr. Malcolm McPhail wrote: Since the earliest period of practice in steam installations, much research and investigation have been given to this interesting and important subject. **Mr. Malcolm McPhail.**

The economical effects due to superheated steam were early recognised, and in the year 1859 the late Mr. John Penn read an important paper on the subject before the Institution of Mechanical Engineers. At this time, however, steam pressures were being increased and the design and construction of reliable superheaters remained unsolved.

As I take a fatherly interest in everything regarding the subject of the superheating of steam, I would like to add a word or two to the discussion which has taken place on Mr. Brownlie's valuable paper.

Mr. Malcolm McPhail.

Since 1889, and until a few years ago, I have been engaged in the designing and installing of superheaters, both flue fired and independently fired, throughout the British Isles and many countries abroad, and for marine purposes.

I may here state that my father and myself were the pioneers of this industry. We spent a great deal of time and money in our investigations, but we succeeded in designing apparatus suitable for exposure to high temperature, and placed it in such a position in the path of the combustion gases in the boiler flues, where it could take care of itself. We did this at a time when superheating was in disrepute, and in consequence many were the difficulties and prejudices we had to surmount. Like most pioneers, we did the spade work. Our imitators got the benefit from a monetary point of view.

The small percentage shown by Mr. Brownlie in favour of superheating must not be taken to represent the actual gain to be derived from the use of superheated steam, and as he is dealing with the boiler house plant only in regard to the generating of steam and not taking into account the benefits accruing from the use of superheated steam after it leaves the superheater and is carried forward to its point of utilisation, I take it that the figure he gives has been arrived at by calculating the amount of heat absorbed by the superheater from the flue gases, and shown as a percentage of the total available heat accounted for when striking the heat balances of the various tests.

It seems ancient history to put forward the many advantages accruing from the use of superheated steam. The saving to be derived by the prevention of condensation in the steam pipes and initial condensation in the engine cylinder well repays the outlay for superheaters in any installation in a very short time. The more modern the engines, the better the results, as they are the more suitable to deal with superheated steam.

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In condensing engines less water is required for condensing purposes, as there is less heat in the exhaust steam when superheated steam is used, owing to the fact that no re-evaporation takes place in the engine cylinders, as is the case when saturated steam is used.

As to the life of a superheater. When visiting a steel works in South Wales a short time back I saw there two downtake superheaters attached to Lancashire boilers in everyday work, which have worked continuously since I installed them in 1903, without being retubed or having cost anything in repairs. This demonstrates that with ordinary handling the superheater's life is almost equal to that of the boiler. On the other hand, where hot air forced draught was used I have known the superheater tubes to have been burnt out in less than six months. In this instance the temperature of the steam leaving the downtake superheater was 840° F. The boiler was of the Lancashire type. This is an extreme case. About 550° F. is a fair average of the temperature of the steam leaving downtake superheaters when the boilers are worked under ordinary conditions—the resultant economy in fuel being about 15 per cent.

I would like to say at this point that at the present time I have no monetary interest in the manufacture of superheaters.

The water level in the boilers is a most important factor to be taken into consideration in the economical production of steam. Reliable automatic appliances are on the market, such as the 'Crosby' type, which are guaranteed by the makers to keep a constant level in the boilers, such apparatus being so arranged as only to admit feed water to the boiler as and when it is required to meet the various demands upon the boiler and to keep the level constantly at the same point in the gauge glass. This is very important. The boiler steams better and more efficiently with a steady and constant level. This is true

Mr. Malcolm McPhail.

of any type of boiler, but more especially with water-tube boilers where the water carrying capacity is small in comparison with the evaporation per hour. It is impossible to regulate such boilers to a nicety by hand. When the water gets too high in the boiler, heavy priming is sure to take place, also the scum and dirt of ebullition are carried forward by the steam into the superheater, where the sediment has a tendency to remain.

I don't agree with Mr. Brownlie that collieries are the worst offenders in regard to waste of fuel in the stokehole. In my experience of over 30 years I have always found colliery owners and engineers very responsive when reliable apparatus for the saving of fuel has been placed before them.

The colliery people were amongst the earliest to adopt superheaters, and that at a time when they were burning fuel of a saleable value of less than 5*s.* (five shillings) per ton, and in many cases unsaleable stuff.

In regard to the proper supervision of the boiler house, especially at collieries, where the engineer's work is scattered and he cannot be two minutes in the same place at one time, and consequently cannot possibly give the requisite time to efficiently supervise the stokehole, I think the suggestion of Mr. Brownlie's—that a properly trained man should be in constant attendance to ensure that the fuel is properly and economically burnt, and to attend to combustion matters generally—is sound and worthy of consideration.

The President.

The PRESIDENT intimated at the close of the discussion that he would give Mr. Brownlie 20 minutes in which to reply, and if after that time he had anything further to say, it would be published in the *Proceedings.*

MR. BROWNLIE'S REPLY.

Mr. David Brownlie.

Replying to the discussion, which had occupied several hours, and intimating that he would deal with the points raised

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more fully in the *Proceedings*, Mr. DAVID BROWNLIE said, in answer to Mr. T. Sugden, that it was true he had not given any figures for the amount of moisture in the steam. It was an extremely difficult matter to determine moisture in steam, and it was nearly impossible to get an average sample of steam. All his figures were averages. With regard to the heating surfaces of boilers, he did not consider this a matter of great importance, and he was limited as to the size of his paper by the Council of the Institute. As to the question of CO_2, it was more convenient to take the samples in the side flues, and he did not see any use in taking CO_2 in the chimney base, because of the porosity of the flues. On the question of superheaters, Mr. Sugden said that the 6·39 per cent. of efficiency in the case of the modern boiler plant on scientific lines needed explanation. If they took 100 parts of heat in the coal, 6·39 per cent. was taken into the superheater, which corresponded to about $8\frac{1}{2}$ per cent. saving in the coal bill. Mr. Sugden had said a number of the percentage figures did not add up. There was always this difficulty about averages. His (Mr. Brownlie's) average was a mathematical average, and not a simple average, and he submitted that the former was the right method to adopt. He might say that he was asked by the Council of the Institute to devote his paper to six sections of the subject, and the paper was not merely on boiler house management in South Wales, or exclusively with inferior coal, or applied to water-tube boilers. Some of the speakers seem to have gone on the assumption that he was dealing only with water-tube boilers; he was speaking of all the boilers in the country, and he was dealing with averages all the time. Also, when he spoke of the colliery industry he did not refer specially to South Wales. Mr. J. W. Davison had said they could not get proper control of the boiler plant because the engineer was too busy. All he could say was that it was

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far better to pay a properly trained man £300 or £400 a year than throw away thousands of pounds in coal value. Mr. Davison also asked how many of the colliery boiler plants he had tested were new plants, and how many were old. Off-hand he did not know. His firm had tested hundreds of plants, and the figures represented a good average of the collieries in this country. He had never 'run down' colliery engineers; taking them generally they were more efficient than the average of other industries, but in the past coal had been too cheap, and hardly worth saving. It was urged that only refuse coal was burned at colliery plants. He had tested a hundred colliery boiler plants, and he declared that 60 to 70 per cent. were burning perfectly saleable coal, and he knew scores of collieries where the best kind of coal was burnt. Replying to Mr. George Roblings, he was afraid the burning of anthracite small was a problem; and he was not prepared to say how to solve it. Mr. G. T. Jones resented his statement that colliery boiler plant was the most wasteful of all. The fact remains that not 20 per cent. of colliery plants in this country had any economisers, and from this cause alone were wasting from 10 to 12 per cent. of the coal bill. This was one of the reasons why colliery plants were the most inefficient, and the lack of the use of superheaters was another. Mr. Henry Davies had challenged his figures as to the percentage of ash. Here again was the trouble about using refuse coal. It was possible, if all the colliery plants in the British Isles were tested, his figures might be wrong, but they were figures yielded by the testing of 100 plants, and that was his experience. It was up to those who had greater experience to prove them wrong. Then Mr. Davies asked about the percentage of moisture in these coals. The figures he had quoted were averages. They knew very well that there were collieries burning colliery refuse containing 30 per cent. of water and 20 per cent. of ash; but this was not the case

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at average collieries. Mr. Browning had complained that he had not made a definite pronouncement as between the Lancashire boiler and the water-tube boiler. It was very difficult to say anything definite on this question. What he had tried to do was to state fairly the advantages and disadvantages of these types of boiler, and it was for the readers of his paper to decide. There were points on both sides. As to stokers, they had got to regard the stoker as a skilled workman. Mr. William Johnson had asked what was a proper staff to look after two Lancashire boiler plants. He (the speaker) would engage a skilled man—a chemist if they liked—to do nothing else but look after the boilers, and not be taken away to attend to other duties. Mr. W. J. Cole had said that mechanical stoking was far better at collieries, and that they could not get proper hand firing. This was a matter of opinion. He could point to collieries where mechanical stokers were scrapped long ago. This was not due to the fault of the mechanical stoker but to the lack of proper intelligent supervision. Mr. F. F. Evans had cited a case at Bristol where 82 per cent. efficiency was obtained with mechanical stokers. He (Mr. Brownlie) did not doubt it, but they could get 80 per cent. with hand firing at Lancashire boilers fitted with economisers and superheaters. It was largely a question of attention, as he had said. He had never stated they could have hand firing with large units of water-tube boilers, but 85 per cent. of the boilers in this country were Lancashire boilers, and the question of mechanical *versus* hand firing on this type of boiler was another question altogether. Mr. Evans gave a lot of information about forced draught. He quite agreed with him that on water-tube boilers forced draught stokers were the best, but Mr. Evans did not say they were the best for Lancashire boilers. Mr. Geldard spoke of mechanical stoking giving 60 per cent. more steam and saving 20 per cent. of coal. He agreed, but he could also

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point to many plants working without mechanical stokers, and giving equally good results by simply employing common-sense methods. They could not take a bad example of hand firing and compare it with a good example of mechanical firing—they must compare averages. The average mechanical firing on Lancashire boilers gave worse results than by hand firing, for the reason that it was more intricate and required more attention, which it did not receive. Mr. Geldard said the figures in the paper about flexibility of steam were ridiculous, and he alluded to dye-works, rolling-mills, etc. He could take Mr. Geldard to dye-works and rolling-mills where the mechanical stokers had been scrapped because they would not answer to the fluctuations. As to the flexibility of coal, they could only work a coking stoker with a coking coal. They could not expect a sprinkling stoker to work with coal that would not sprinkle mechanically. Mr. Geldard said that mechanical stokers could be used at collieries. In his (Mr. Brownlie's) view a colliery boiler plant was about the worst example for mechanical stoking, because it had to burn all kinds of coal, and could not be expected to differentiate between these various grades of fuel and work satisfactorily. Mr. Geldard had referred to steam jets, and questioned his figures. According to his (the speaker's) experience, the average mechanical stoker took $6\frac{1}{2}$ per cent. of the steam. Makers confessed to a modest 1 per cent., and one firm admitted from 4 to 5 per cent. If looked after properly, it should not take more than $3\frac{1}{2}$ per cent., but he had met plants where over 20 per cent. was being taken.

Mr. G. A. Budge had hinted that his 6,000 lb. steam evaporation was too low, and stated that with a 'Bennis' mechanical stoker he had easily got 10,000 lb. He (Mr. Brownlie) did not doubt it, but the average was 6,000 lb. Mr. A. J. Ashton had quoted his statement that the average saving of coal due to economisers varied from 1·6 per cent. for 100 colliery boiler

plants to 18·5 per cent. for modern plants, and asked whether this 1·6 per cent. did not convey the impression that economisers actually working saved only 1·6 per cent. All he could reply was, as the paper showed, he was speaking in averages, and if people were misled he could not help it. Mr. Ashton objected to the statement that most economisers were installed on rule-of-thumb principles. The makers were in an unfortunate position. If they urged the putting in of an economiser to suit the existing plant, they were often told that the cost was too great, and they had either to put in an unsuitable economiser or lose the job. It was the steam user who was chiefly to blame. Major Utting advocated air heaters. Roughly speaking, he (Mr. Brownlie) agreed these ought to be combined with economisers to get better results. Mr. David Brownlie.

Mr. Rushworth had said the life of an economiser ought to be twenty years, but the average life was about ten years, and was not as long as it ought to be. Mr. F. F. Evans was a strong advocate of forced draught, but most boilers in England, as he had already stated, were Lancashire boilers, and in his opinion forced draught was not as good for them as induced draught. He agreed that forced draught was better for water-tube boilers. Mr. Chadwick had represented him as saying that forced draught was necessary in all cases. This was not quite an accurate version. What he did say was that in average cases some form of mechanical draught was necessary to get the best results. Mechanical draught was certainly necessary in connection with burning anthracite. With reference to coverings for laggings spoken of by Professor Bacon, a covering of 85 per cent. magnesia was the best. Asbestos was used not so much as a non-conductor as a binding agent.

Mr. Brownlie writes, further replying to the discussion :—

The length of the discussion is so great, and such a variety of points have been raised, that it is utterly impossible for me,

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because of lack of space, to reply separately in detail to every speaker. Accordingly I have done my best to divide up the discussion, and to reply under general heads.

In reply to Major E. Ivor David and other speakers, the 100 colliery boiler plants are not all exceptionally bad cases, but are, in my opinion, a true average for the colliery industry. It is not, as might be expected, the firm with a bad plant that calls for advice, but rather the firm that is fairly up-to-date, and on this account realises the value of specialists. The particulars Major David gives of what is possible with a really modern plant are strong proof of my contention that a number of millions of tons of coal are being wasted per annum in the colliery industry alone on the present general out-of-date plants.

Also, in reply to Mr. J. W. Davison, the 100 colliery boiler plants tested were a good average as regards age, and colliery boiler plants in general that have been put down during the last few years are very little more efficient than much older plants.

Mr. J. W. Davison, Mr. George Roblings, Mr. G. D. Jones, Mr. H. Davies and other speakers point out that there is only 11·5 per cent. of ash in the coal used on the 100 colliery boiler plants, and say that this is abnormal, as collieries generally use inferior fuel. I can assure these speakers, however, that this is a fair average for the coal used at collieries during the last ten years. Whilst, of course, much refuse and inferior coal is undoubtedly utilised at collieries, it is surprising how much good quality coal is used, and, in my opinion, collieries in general do not make anything like the best use of refuse coal. I know many collieries where nearly all the coal burnt under the boilers is high class saleable fuel. I may say, however, that there is no doubt that South Wales in general is better in this respect than most other districts, and the amount of refuse coal utilised in South Wales is very large.

Mr. F. F. Evans points out that some of the largest colliery owners in South Wales are using thousands of tons of good class saleable coal, whilst at the same time refuse coal, which could easily be burnt under the boilers, is being thrown on the tip. The conditions as regards refuse coal in South Wales are also peculiar, because such fuel is anthracitic in character, which makes efficient utilisation extremely difficult. I am in accord with Mr. George Roblings, Mr. W. J. Cole, and Mr. F. F. Evans that the most promising results are obtained with water-tube boilers, forced draught, and mechanical stokers with a very large grate area. Much further work is undoubtedly required in this direction. Mr. David Brownlie.

Mr. H. Davies asked what is the explanation of the great difference in the amount of coal burnt per square foot of grate area per hour between the 100 colliery boiler plants (168·9 lb.) and a typical modern plant run on scientific lines (32·1 lb.). The difference is due to various reasons. In the first place, the coal used at the colliery plants is much inferior. Although the ash was only 12·5 per cent. as against 11·5 per cent., the heating value is much less, namely, 10,500 B.Th.U. as against 11,980—a big difference. Also, the colliery coal was much wetter, probably something like 12 to 15 per cent. as against 5 per cent. The modern plant is, however, much better equipped with mechanical draught, together with a CO_2 recorder, so that a shorter grate and much thicker fires are used, with a greatly increased draught. Consequently the percentage of CO_2 is 12 per cent., as against only $7\frac{1}{2}$ per cent. on the collieries. The duration of the tests has nothing to do with the comparative figures. The real cause of the inferior results on colliery plants is lack of the most up-to-date equipment and lack of good supervision.

In reply to Mr. G. D. Jones, Mr. H. Davies, Major E. Ivor David and various other speakers, I have stated that colliery

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boiler plants are giving the worst result of any industry, but I do not infer from this that the colliery engineer is to blame. As I have stated repeatedly, in this and many other papers, I consider the average engineering at collieries to be of a very high order indeed. The reason why the boiler plant is neglected, which it certainly is, seems to be a relic of the days when coal at the pit head was only valued at a few shillings a ton, and not worth saving. In any case, the average colliery engineer has far too many things to attend to, which is the fault of his management, so that he neglects the boiler plant.

As regards the statements of Mr. W. Browning and Mr. W. O'Connor: In my opinion it is a thoroughly wrong policy to regard a fireman as a mere unskilled labourer who could be picked up anywhere. Efficient steam generation is a highly skilled job, and firemen ought to be trained, paid, and regarded on an equal footing with plumbers, mechanics, and other skilled artisans, and the human element in the firehole is a matter of primary importance.

I am quite at a loss to understand why Mr. J. W. Davison considers it is not possible to run colliery boiler plants just as efficiently as in any other section of industry, power stations included. To allow coal to be wasted is bad management, whether in a colliery boiler house or that of any other industry; and I think with Mr. W. H. Heppell, Mr. W. Johnson, and Professor Bacon that every colliery of any size at all ought to have an engineer in charge of the boilers, and no other duty to distract his attention. The saving that would result, say 10 to 25 per cent. of the coal bill, would repay his salary many times over, and I agree with Mr. W. Johnson in this respect. Mr. Heppell points out that colliery boilers often have to run all the year round, and there is no time at the week-end to attend to them.

Mr. W. Johnson asked what I would consider to be a proper

staff to look after two batteries of six boilers each, and what was a justifiable outlay to secure proper control of boiler plants. I presume these boiler plants would be entirely separate, and apart from the existing labour, say three firemen and one ash wheeler at each plant, if hand fired, or say two men if mechanically fired with mechanical coal and ash conveyers. I would suggest the appointment of a highly skilled man as boiler superintendent over both the plants, at a salary of, say, £400 a year. This would be the only extra cost required in the way of labour. I would recommend also that each plant be fitted with a boiler-feed meter and accessories in the way of by-pass, etc., at a cost of, say, £120 per plant, and also a modern CO_2 recorder, costing, say, £75 per plant. The regular weighing of the coal would in most cases cost little or nothing, and a further £100 would buy a good hand-set of pyrometers, draught gauges, etc. On some such lines as these, bearing in mind each plant has to be considered on its merits, I know from experience that a most handsome nett saving would result. **Mr. David Brownlie.**

In reply to Mr. F. F. Evans, who states that my tables do not apply to up-to-date plants, I have given on page 413 a table dealing with modern boiler house management, showing 78·68 per cent. nett working efficiency on Lancashire boilers. Mr. Evans is evidently a whole-hearted water-tube boiler man, but I can assure him I am very well acquainted with modern boiler plant developments. He ignores the fact, however, that the majority of the boiler plants of Great Britain are small, and always will be so, and for such conditions the Lancashire boiler has many marked advantages.

The average water-tube boiler installation in this country is nothing like 5–10 times the evaporation per boiler as compared with Lancashire boilers. The standard 30 feet by 8 feet Lancashire boiler will evaporate 8,000 lb. per hour under proper conditions, but in averages is only evaporating

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about 6,000 lb. The average water-tube boiler installed is about 20,000 lb., and boilers of over 40,000 lb. are comparatively rare. Also, Mr. Evans may be interested to know it is quite possible to work a modern Lancashire boiler installation at 77·5–80 per cent. nett working efficiency. Mr. J. H. Lea's statements in this connection are of interest.

In reply to Mr. W. H. Reynolds and Mr. F. F. Evans : As regards the efficiency of water-tube boiler plants, Mr. F. F. Evans thinks my average figure of 69 per cent. too low, and says that it should be 75 per cent. ' on a properly controlled and equipped modern generating station, even when burning a low grade of fuel.' The generating stations of Great Britain are not properly controlled and equipped. Most of them have no scientific method of working the plant, and a large number of them do not even possess a water meter or a CO_2 recorder in accurate running order. It is for this reason the average efficiency is only 69 per cent. It is all nonsense to suppose water-tube boilers and power stations are always efficient. The very reverse is often the case, and some of our largest power stations, with water-tube boilers, forced draught, and mechanical stokers all complete, are a disgrace to the engineering profession.

As regards economisers : In reply to Mr. A. J. Ashton, in my opinion, an economiser will save 15–20 per cent. of the coal bill. I have certainly never come across a case of $24\frac{1}{2}$ per cent. saving, and such a figure is abnormal, either due to extremely cold inlet water or some defect in the boiler installation, so that the boiler exit gases are too hot. The 1·6 per cent. saving in the colliery industry is, of course, the average saving due to economisers, and is very low because collieries will not, as a rule, install economisers, less than 20 per cent. of colliery boiler plants being equipped at all, and most of these installations are too small. I certainly think economisers are

erected on rule-of-thumb lines, and I have seen too many installations to think otherwise. It may be the custom of Mr. Ashton's firm to obtain 'when possible' the calorific value of the fuel, evaporation, analysis of flue gases, etc.; but the trouble is that it is only possible to get this information on, say, 5 per cent. of the boiler plants of Great Britain. Mr. David Brownlie.

In consequence, all over the country economisers are installed on purely arbitrary considerations, that is, as a rule, 72 or 96 tubes per Lancashire boiler. I can assure Mr. Ashton that there are plenty of economiser plants at work in this country so badly designed and installed that the hot flue gases have to be by-passed to the chimney to get enough draught to burn the coal. In general, I quite agree that it is the steam user who is primarily to blame.

I am in accordance with Mr. Ashton and Mr. David Rushworth that cast-iron economisers are much superior to steel, and I know—as explained by Mr. Rushworth and Mr. R. Clark—that cast-iron economisers can be used at over 200 lb. pressure by having a special arrangement of a feed-pump between the boiler and the economiser.

I am in full accord with Major Utting as to the value of air heating, and the only reason I did not mention it in the paper was lack of space. The ideal combination for a large modern water-tube boiler plant is superheaters, air heaters to supply a hot forced draught of, say, 300° F. to the mechanical stokers, and cast-iron economisers to heat the feed-water, with a feed pump between the boiler and economiser.

As regards mechanical draught (forced, induced, and balanced), mentioned by a number of speakers—Mr. V. R. Chadwick, Mr. W. Whittaker, Mr. Algar W. Bell, Mr. W. O'Connor, Mr. F. F. Evans, and Mr. J. R. Chalmers—there is no doubt that it is a thoroughly sound proposition. For water-tube boilers and mechanical stokers the ideal is forced draught,

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combined with either chimney draught or a small induced draught set. For Lancashire boilers, that is 75 per cent. of the coal of the country, I think induced draught is preferable to forced draught, but the latter will also give good results.

Mr. F. F. Evans seems to look at this matter only from the point of view of the water-tube boiler. It is quite true that mechanical forced draught on water-tube boilers with mechanical stoking takes less than 1 per cent. of the steam production of the plant, but this does not apply to Lancashire boilers, where the figure is much higher.

As regards the results being given by mechanical firing in comparison with hand firing, Mr. F. F. Evans, Mr. Geldard, and Dr. S. Wolff in particular, strongly contest my statement that in averages mechanical firing is giving no better results.

Mr. F. F. Evans states that he finds on the result of many hundreds of tests that mechanical firing on both internally and externally fired boilers is superior to hand firing, when comparison is made over a long period. My experience of 500 boiler tests, an inspection of about 2,000 plants during the last 15 years or so, has been different, and in my opinion mechanical firing on cylindrical boilers is, in averages, giving worse results than hand firing. If it is necessary for Mr. Evans to write a complete paper to controvert me, I hope he will get busy on it, and I will turn up to join in the discussion.

Mr. Geldard says 'the initial cost of the machine is saved in a year or two.' This is typical of the loose statements continually made with regard to mechanical stoking—the assumption that if mechanical stokers are installed an economy must result—an assumption for which there is not the slightest justification.

In reply to Dr. S. Wolff, I do not agree that mechanical firing beats hand firing on practically every point, and in this

connection it would be interesting to know how many thousands of mechanical stokers have been thrown on the scrap heap in the last fifty years. Dr. Wolff's analogy of a doctor giving all his patients the same medicine seems to me to apply rather to some firms of mechanical stoker makers, who recommend their own stokers for every possible condition, irrespective of coal to be burnt, the attention, the amount of labour, the variation in evaporation, etc. The consequence is that mechanical stoking gets into bad repute. We have the usual confusion about averages, and advocates of mechanical stoking will persist in taking favourable cases for mechanical stoking, whilst averages are quite all right for hand firing. It is not misleading at all to give average figures for mechanical stoking, and if only special favourable cases are taken, then also equally abnormal conditions must be considered for hand firing. Mr. David Brownlie.

I may say that I am not an opponent of mechanical stoking, which, under scientific conditions, is on the whole superior to hand firing, but since these conditions do not obtain, we have to consider mechanical stoking as it is working under unscientific conditions.

An important point in connection with the efficiency of a boiler plant is the quality of the coal used, and I quite agree with Mr. W. Browning that mechanical stokers will give better results with good quality coal and a steady demand for steam, but trouble arises when low grade coal is used, together with greatly varying evaporation, so that in many cases equally good results could be obtained with hand firing.

Mr. F. F. Evans states that the average CO_2 for mechanically fired plants is $8\frac{1}{4}$ per cent., and only $7\frac{1}{2}$ per cent. for hand fired plants, and that this proves my statement that mechanical firing does not give better results than hand firing to be wrong. Mr. Evans falls into the popular error

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of supposing that higher CO_2 necessarily means higher efficiency. It is quite possible to have 15 per cent. CO_2 and to be getting much worse results than if 5 per cent. CO_2 was obtained. The reason is that if CO is present there is a serious loss in efficiency, and what is required is high CO_2 with no CO. A plant with high CO_2 and CO as well will often give much inferior results to one with low CO_2 and no CO.

I quite agree with Mr. Evans that it is difficult to get men to undertake the laborious work of hand firing, and have expressly stated in the paper that this is the chief disadvantage of hand firing.

Mr. Geldard says that it is quite a common thing for mechanical stoking to halve the cost of labour. Here, again, Mr. Geldard is speaking presumably of special cases, that is, large boiler plants of, say, six Lancashire boilers or over, whereas I am speaking of average conditions, the majority of boiler plants being small, in which cases the saving in labour is *nil*.

In reply to Mr. W. Whittaker, I quite agree that a hand fired furnace with mechanical moving grates has very little wear and tear and cost of upkeep in comparison with a mechanical stoker.

In answer to Mr. Geldard, it is possible 'big texture firms in the North' will laugh at 50–60 per cent. efficiency. This may be so, but it does not alter the fact that boiler plants in general, hand and mechanically fired, are inefficient, and that nearly 500 plants which I have tested show an efficiency of 58 per cent., and nearly 2,000 plants I have inspected are working on the same lines. Mr. Geldard criticises the figures given on page 421, but he apparently does not understand the difference between simple averages and mathematical averages, and the figures in this table are simple averages.

Mr. Geldard goes on to say it is a common thing to get

16,000–17,000 lb. evaporation on a Lancashire boiler 30 feet by 9 feet, and then remarks casually the coal had $3\frac{1}{2}$ per cent. ash. It seems to be impossible for Mr. Geldard to understand that I am speaking in averages as applied to all the coals of the country, and not to freak conditions with high quality coal. All I can say is that Mr. Geldard's experience as regards the working of mechanical stokers, especially with regard to flexibility in steam output and quality of coal burnt, is different to mine. Mr. David Brownlie.

Mr. F. F. Evans has evidently not read the paper carefully when he challenges my statement that mechanical stoking does not increase the evaporation of the boiler plant. I have stated in what I thought was the clearest manner that the summary of advantages and disadvantages of mechanical firing applies to cylindrical boilers only, and not to water-tube boilers at all. It is no use comparing hand and mechanical firing on water-tube boilers, because in the latter case we are compelled to put up with mechanical stokers whether we like them or not, because of the size of the units. Mr. Evans' criticism on this point, therefore, has nothing to do with the paper. Again, on the question of the reduction of flexibility in the quality of coal used by the installation of mechanical stokers, Mr. Evans seems to be labouring under the same error.

With regard to the Bristol figures, I am well aware that the 'Underfeed' self-contained travelling grate stoker is a very efficient machine, and the future of mechanical stoking on water-tube boilers seems to be between this type and the multiple retort stoker.

Mr. Geldard says I speak of scientific control of the boiler-house as if it is something new, and states that as long ago as 1897 he knew of a firm who introduced such methods. I have said nothing of the kind, either in this paper or anywhere

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else, and, as far as I know, the first boiler test was carried out by Josiah Parkes as long ago as 1819.

In reply to Mr. Malcolm MacPhail's very interesting remarks, the figures for superheating are the averages, and, as Mr. MacPhail knows, steam users in this country cannot be got to realise the benefit of superheating. The efficiency figures are based on the heat absorbed by the superheaters, and do not include the extra benefits of superheated steam in connection with the utilisation of steam.

With regard to Mr. C. E. Foster's remarks, I am very sorry I have not been able to give more attention to the important subject of pyrometers, and if it is possible to take the temperature in the actual boiler furnaces by means of pyrometers, a distinct advance will have been made in scientific methods of boiler plant control.

As various speakers have pointed out—chiefly Mr. S. B. Haslam, Major Ivor David, and Mr. Arthur Grounds—there is no doubt that the CO_2 recorder is a necessity on all but the smallest plants, and the losses caused by excess air, with consequent low CO_2, are very serious.

In answer to Mr. J. P. O'Callaghan, I could only give a passing reference to the chemical treatment of the boiler feed-water, since this was not one of the subjects specified by the Council, but, of course, like most engineers, I am well aware of the enormous waste in fuel caused by hard boiler feed-water.

There is no question as to the value of steam meters in controlling steam consumption, but most steam users to-day will not look at them, and if Mr. Brooker is convincing people of their necessity he is doing very valuable work.

Mr. W. H. Reynolds states that my statistics 'confirm the information published by the Technical Department of the Coal Control Board.' I am sure Mr. Reynolds has no wish to

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do me an injustice, but I simply cannot allow such a statement to pass unchallenged. The 'information' published by the Coal Control Board consisted chiefly of pious platitudes and opinions on the working of a few boiler plants. I have been testing and examining boiler plants years before the Coal Control Board was ever heard of, and when it was formed I must have made a complete scientific investigation of over 300 plants, and inspected, on the lines of the Coal Control Board, at least 1,250 plants in addition. It is rather unjust, therefore, to say the least of it, that my work should 'confirm that of the Coal Control Board,' which, at any rate to my knowledge, never tested a single boiler plant.

Mr. Reynolds says the Coal Control Department had 'a large body of recognised engineers throughout the country' engaged on fuel economy. The appointment of the 400 experts without salary was, in my opinion, one of the most ludicrous proceedings in the war. Many of the gentlemen appointed were of course well-known engineers, but the antics of some of the 400 will provide material for merriment for years to come whenever engineers congregate.

Further, in reply to Mr. Reynolds, any statistics I have seen relating to power houses of this country do not give the particulars of the performance of the boiler plant.

Vote of Thanks to Mr. Brownlie.

The President.

The President said they would all agree that Mr. Brownlie had given them a very interesting and clever paper, which covered a great deal of ground, and had evoked a useful discussion. He was sure they would all wish to pass a hearty vote of thanks to Mr. Brownlie. (Applause.) They had had an instructive afternoon and evening.

THE IRON ORES OF SOUTH WALES.

By R. W. Atkinson, B.Sc., F.I.C.

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The useful ores of iron are of two kinds, oxides and carbonates, and both kinds exist in South Wales, the former being probably of Triassic age though found in the Mountain Limestone, the latter in the beds of the Coal Measures.

It will be convenient to consider the carbonates of iron first, for although at the present time they are not used in the furnaces in South Wales, they were the ores which first started the manufacture of iron in this district. They were smelted with charcoal in the first place, and only when the wood began to fail was the associated coal used for smelting.

Up to quite recently a good deal of this class of ore was raised in the winning of coal, but it was all sent to be smelted in furnaces in the Midlands, not being able to compete here with the richer ores imported from abroad, and the purer haematites found in this district.

These carbonate ores pass under a variety of names : clay ironstone, ball-mine, pins, black-band, and coal brasses—the last a very confusing name, as it is also given to the iron disulphide also found in coal-seams. The name is probably due to an association in some cases between the clay ironstone and iron disulphide, the mass having a brassy colour suggesting pyrites.

In clay ironstones the iron carbonate is mixed with clay, the ball-mine and pins are nodules distinct from the clayey matter surrounding them, and black-band is ferrous carbonate

mixed with 10 per cent. or more of coaly matter, sufficient to allow the mass to be roasted in heaps without additional fuel.

Dr. Percy, in his classical work on 'Iron,' gives a large number of analyses of various kinds of clay ironstone from all the coalfields, showing, of course, very great differences in composition. We may take it that there are about four distinct varieties of these ores :—

1. Compact, heavy and black with pisiform structure when broken.
2. Compact and crystalline, resembling a dark coloured mountain-limestone.
3. A variety similar to (1), but mixed with pyrites.
4. Shaly looking, containing enough coaly matter to burn and called black-band.

Typical analyses of these varieties are given below. Other analyses of a sample of a seam containing both clay and nodules from a Monmouthshire mine are given, the proportions of clay and nodules being about equal.

Analyses of Clay Ironstones and Black-band.

	1 per cent.	2 per cent.	3 per cent.	4 per cent.
$FeCO_3$ . .	68·71	75·71	17·74	54·97
$MnCO_3$ . .	0·42	1·20	. .	0·80
$CaCO_3$ . .	9·36	5·89	14·10	12·03
$MgCO_3$ . .	11·80	11·59	12·06	22·43
Fe_2O_3 . .	—	2·86	—	—
FeS_2 . .	0·22	—	49·70	0·27
P_2O_5 . .	0·17	—	—	trace
Clay, or insoluble residue . .	—	0·43	—	0·11
Coaly matter .	8·87	1·67	6·10	10·03
	99·55	99·35	99·70	100·64

CLAY AND NODULES (MONMOUTHSHIRE).

	Nodules	Clay	(Molecular ratios)
Silica	10·97	62·52	4·1
Alumina	2·47	25·62	1·0
Fe_2O_3	2·07	—	
FeO	41·10	—	
MnO	0·59	0·78	
CaO	7·55	3·64	
MgO	1·79	1·64	0·56
K_2O	0·56	1·38	
Na_2O	0·29	0·64	
CO_2	32·65	—	
H_2O	—	3·70	
	100·04	99·92	

Clay ironstones are found in all horizons of the coal-measures, but, in the eastern part of the coalfield at least, the main beds upon which the iron works depended for many years were those underlying the 'Lower Four Feet Coal' (old coal and Gellideg). They were known mainly as :—

1. Spotted vein ; also called black pins, upper pins, and black vein.
2. Red vein ; also known as blue vein, llyfra, and pinna.
3. Little blue vein ; also as Jack vein.
4. Big vein, and knobbly.

Many of Dr. Percy's analyses were made on samples from these veins in different districts, and show very great variations in composition, due for the most part to differences in amount of extraneous matter. When allowance is made for the silica, water, and organic matter, the samples from the Blaenavon district give percentages of FeO ranging from 51 to 58·6, whilst those from the Pontypool veins vary from 36·5 to 53·4 per cent., most of them well under 50 per cent. The Dowlais samples are nearer to those from Blaenavon, ranging from 48·3 per cent. to 55·6 per cent. FeO.

The sample of clay-ironstone marked 2, containing 75·71

per cent. $FeCO_3$ (48·42 per cent. FeO), was picked out of some coal from the Abercynon pits, and unfortunately the seam could not be identified, though it was in the neighbourhood of the Four Feet, Six Feet, or Nine Feet seams. It forms a rounded nodule coated on the outside with coaly matter, and when broken proves to be composed of crystalline particles of a dark colour, due to the 1·67 per cent. of coaly matter disseminated through the crystals. It is a true spathose, resembling in composition that which was mined in the Brendon Hills, Somerset, except in the smaller percentage of manganese contained in the coal-measure specimen.

In the days when clay ironstone was smelted in South Wales, blast-furnace managers reckoned that $3\frac{1}{2}$ cwt. of raw ore, or $2\frac{1}{2}$ cwt. of calcined ore, yielded 1 cwt. of pig-iron, roughly 29 per cent. metallic iron. When properly cleaned it was considered that the veins would average 28 per cent. Fe, and the pins 32 per cent. Fe, and as the quantities were about equal, the average of both was 30 per cent. West of the Neath river the average was higher, at Brynamman it was $34\frac{1}{2}$ per cent. Fe.

The question may be asked as to what quantity is available in South Wales if it were needed. The writer has not seen any recent estimates, but in 1880 Mr. T. Joseph reckoned that in the Merthyr and eastward region, including irregular workings, there were $4\frac{1}{4}$ million tons of ore per square mile, whilst in Aberdare and westwards there were 3·9 million tons per square mile. This would mean, allowing an average of 25 per cent. metallic iron, $1\frac{1}{16}$ and just under 1 million tons respectively of metallic iron per square mile. If this is a correct estimate, surely it is too valuable an asset to be thrown on to the rubbish heap !

How have these ores been formed ? The beds are found alternating with coal and shale, and most frequently occur in the fireclay; but as all beds of fireclay do not contain them,

it is evident that the association with these beds is an accidental one, and that the iron carbonate has been introduced under some special conditions.

The original theory propounded by Mr. J. Lucas in 1873 was that they originated in lagoons or alluvial swamps of the deltas of the Carboniferous period, which would expose surfaces to the air, but subject to being covered by floods. Carbon dioxide, formed by decomposition of the vegetable matter in the lagoons, meeting with ferrous oxide in solution would produce the ferrous carbonate, which, mixed with the mud of the lagoon, would form clay ironstone. By some process of segregation the nodules would be formed. This explanation implies that they were formed in shallow water, but there are deposits which are associated with rocks containing deep sea fossils, as in the Yoredale rocks.

Another difficulty arises when we ask whence the ferrous oxide in solution came. The results of the *Challenger* expedition showed that at great depths the bottom of the sea was covered with a fine clay consisting of silica, alumina, and iron, and that nodules of manganese oxide were very common. Could the presence of iron nodules in the clay arise in a similar way ?

Another explanation, suggested by various authors, and summarised by E. C. Harder in a ‘professional paper’ issued by the U.S. Geological Survey in 1919, is that iron-depositing bacteria were the agents in the growth of these clay ironstones. It has been observed that in certain waters deposits of iron hydroxides are formed as the result of the physiological activities of some species of bacteria, and that in bog iron ores remains of such organisms have been found which prove the connection. Details cannot be entered upon here, but it seems probable that if the bog iron ores have been produced by bacterial action, the iron deposits in the clays of the coal measures may have originated in the same manner.

At the present time the oxides of iron are the most important in the smelting of iron, and we may now consider them in some detail. These ores are found in South Wales in a narrow strip of Mountain Limestone, which crops out from Rudry to this side of Bridgend, and they have been worked more or less extensively at various places along this line, though at the present moment the only mine actually bringing the ore to the surface is situated at Llanharry, about $1\frac{1}{4}$ mile W.S.W. from the Llantrisant station on the Great Western Railway main line west.

The geological position of the ore deposits has been described in detail by Principal T. Franklin Sibly, in Vol. X of the 'Special Reports of the Mineral Resources of Great Britain,' issued by the Geological Survey, and those who wish to know more about this matter will find there a wealth of information gathered from his close personal inspection of this district, and from previously published information from all sources, as well as a comparison with the similar deposits of iron ore in the Forest of Dean.

The writer's own knowledge of this ore-field has mainly been derived from the mine at Llanharry, though experience of three other principal mines worked in the past has not been wanting, *i.e.*, from the Garth, Mwyndy, and Trecastle mines.

At Llanharry the Carboniferous Limestone and the overlying Millstone Grit dip nearly due north at an angle of about 32° ; upon these rest horizontally the beds of Keuper Conglomerate, and above these again there is a superficial covering of glacial gravel, thick on the east side but thinning out towards the west. On the east side of the mine the glacial gravel soon cuts out the Keuper Conglomerate and then rests directly upon the Carboniferous Limestone.

The ore is found for the most part along the top of the limestone, where it is overlain by the Millstone Grit and the

Keuper Conglomerate, though it also extends in an irregular manner into the body of the limestone, failing, however, in depth. It does not rise into the Millstone Grit shales and only to a very small extent upwards into the Keuper Conglomerate, but seems to follow cracks and joints in the main limestone, masses of ore being separated from one another by intervening bodies of limestone, more or less dolomitic. The deposits are here and there intersected by faults.

After this rather sketchy description of the manner in which the ore is deposited, we may next consider the character of the ore itself as a mineral.

All the iron found in this mine is fully oxidised, with the exception of a minute quantity of ferrous carbonate existing in the dolomitic limestone, and occasional occurrences of pyrites ; there is no magnetic oxide, all the ore being composed of ferric oxide and its hydrates.

Speaking generally, the anhydrous oxide of iron occurs in two forms, one crystallising in the rhombic system, *Red Haematite,* the other, *Martite,* in the cubic system. To the best of the writer's knowledge the latter is not found at Llanharry.

There are stated to be several hydrates of ferric oxide : (1) *Göthite,* crystallising in the rhombic system with one molecule of water combined with one molecule of Fe_2O_3 ; (2) the *Brown ore of Hüttenrode* = xanthosiderite, which contains one molecule of Fe_2O_3 combined with two molecules of water ; (3) *Turgite,* with two molecules of Fe_2O_3 combined with one of water ; and (4) *Limonite,* two molecules of Fe_2O_3 with three molecules of water. These are all given as distinct mineral species, but the text-books also give a hydrate, $Fe_2O_3.3\ H_2O$, obtained by precipitation, and a bog iron ore (*quellerz*) from Russia was stated by Hermann to have the same composition as the precipitated hydrate.

The anhydrous oxide of iron known as 'red haematite' is

found at Llanharry in several forms, crystalline, massive, and as a red unctuous powder resembling the greasy red haematite of the Cumberland district. The crystalline variety usually lines cavities in the hard massive ore which is commonly known as 'blue ore,' because a freshly made fracture is almost sky-blue in colour. This 'blue ore' is extremely hard and difficult to mine; it contains silica intimately mixed with the iron oxide, as the analyses of two specimens will show.

'Blue Ore.'

	1 per cent.	2 per cent.
Fe_2O_3	89·06	88·66
SiO_2	11·06	10·04
P	0·019	—
Combined water .	—	1·30
	100·139	100·00

It is rarely possible to see the silica with the naked eye, but probably a microscopic section would reveal it. When the blue ore occurs in a pure state, *i.e.*, free from silica, the cavities are often lined with beautiful crystals of a transparent rich red colour, which though minute are readily seen with the magnifier, and under a strong light the red colour shines out brilliantly. No mention is made in text-books of the existence of transparent red crystals of anhydrous ferric oxide, and these crystals are free from almost all impurity, as the succeeding three analyses will show.

Red Transparent Crystals.

	1 per cent.	2 per cent.	3 per cent.
Fe_2O_3	98·66	98·50	98·80
SiO_2	0·65	—	—
H_2O	0·60	0·44	—
	99·91	98·94	98·80

Besides the hard blue ore the anhydrous ferric oxide is found as an unctuous, shining red haematite giving a bright red powder, and is much softer than the blue ore. It also occurs as an earthy, compact red ore with a bright red streak. Some specimens show highly polished surfaces, like the ' slickensides ' in coal.

	Unctuous per cent.	Earthy per cent.
Fe_2O_3 . . .	96·37	96·53
SiO_2 . . .	2·00	1·33
H_2O . . .	0·80	1·40
P	0·017	0·011
	99·187	99·271

The red kidney hæmatite does not seem to occur in this district, but a water-worn lump of ore was once found which seemed to have lines marking the kidney structure, and which yielded 99 per cent. of Fe_2O_3. It was in all probability a lump of blue ore which had been polished by running water and had developed ribs, suggesting the kidney ore of Cumberland. The polishing is not of recent occurrence, but must have taken place at some early period in geological history.

The hydrated oxides of iron exist in several forms, mainly as a compact brown ore, often with a reddish surface tinge, and giving a brown streak and powder. Sometimes in the crevices minute crystals are found either reddish in colour or of a black metallic lustre.

It will be seen from the adjoining analyses that the molecular ratio $\frac{Fe_2O_3}{H_2O}$ is approximately unity, and this is true of all the brown ores examined.

Ordinary Brown Haematite, Llanharry.

	1	2	3	4
	per cent.	per cent.	per cent.	per cent.
Fe_2O_3 . .	89·61	89·19	89·36	86·36
H_2O . .	9·05	9·40	9·45	8·43
SiO_2 . .	1·33	*nil*	1·19	5·22
P . . .	0·012	—	—	—
	100·002	98·59	100·00	100·01
$\frac{Fe_2O_3}{H_2O}$ . .	1 : 0·9	1 : 0·93	1 : 0·94	1 : 0·87

At times the brown ore occurs in close association with anhydrous red ore, and then it is sometimes difficult not to get a small quantity of red ore into the specimen for analysis. Thus one such specimen gave the following figures :

	Brown	Red (soft red ochre on outside)
Fe_2O_3 . .	91·81 per cent.	97·20 per cent.

The constancy of the ratio, however, shows that the error from this source is negligible.

The brown ore also assumes the structure of kidney ore, resembling in form, though not in composition, the kidney haematite of Cumberland. It frequently develops a banded structure, bands of brown and yellow alternating, giving it a very attractive appearance. There is no practical difference in the composition of the two coloured bands, but in the formation of these banded kidneys some physical conditions must have varied.

Banded Brown Haematite.

	Ordinary Mixed	Dark Brown no Yellow Bands	Yellow Bands
	per cent.	per cent.	per cent.
Fe_2O_3 . .	88·03	89·24	87·20
H_2O . .	11·97	10·41	10·70
	100·00	99·65	97·90
$\frac{Fe_2O_3}{H_2O}$ . .	1 : 1·21	1 : 1·03	1 : 1·09

Here again we get practically the ratio 1 : 1, and this constancy suggests that it is the mineral species '*göthite*' which constitutes the bulk of the brown ore in these ore deposits. Principal Sibly found that the Brush ores of the Forest of Dean gave the same ratio of Fe_2O_3 to H_2O, and they also closely resemble these South Wales ores in appearance and occurrence.

Next come the bright yellow ores which commonly go under the name *limonite*, and are stated in treatises on Mineralogy to have a molecular ratio $\frac{Fe_2O_3}{H_2O} = \frac{2}{3} = \frac{1}{1 \cdot 5}$. In the course of examination of large numbers of specimens of the yellow ore, apparently free from any admixture with red ore, the highest molecular ratio encountered has been 1 : 1·25, and in an exceptionally clean specimen of yellow ochre from this mine the ratio was 1 : 1·05, almost the same as in the yellow band of the kidney ore. It should be noted that calcite runs through this yellow ore and is difficult to separate mechanically, so that it is possible that the higher ratio of water in some cases may be due to the presence of a small quantity of carbon dioxide, when the water is determined by loss on ignition.

Here are four analyses of fairly clean yellow ore which show ratios very nearly unity. The last column shows the composition of No. 3 when calculated free from gangue, and may be compared with the calculated composition of the compound $Fe_2O_3.H_2O$.

Composition of Yellow Ores.

	1	2	3	4
	per cent.	per cent.	per cent.	per cent.
Fe_2O_3 . .	88·00	80·61	88·23	90·05
H_2O . . .	10·40	10·10	9·74	9·95
SiO_2 . . .	1·60	6·90	1·10	—
Soluble gangue .	—	2·36	0·93	—
	100·00	100·00	100·00	100·00
$\frac{Fe_2O_3}{H_2O}$ . .	1 : 1·06	1 : 1·11	1 : 0·98	1 : 0·98

	Calculated from formula.
Fe_2O_3	89·86 per cent.
H_2O	10·14 ,,
	100·00

To remove the possibility of the ratio being affected by the presence of calcite, a specimen of soft yellow ore was analysed directly, and also after washing with acetic acid, then distilled water, and finally dried at 100° C. The result confirms the suspicion that the higher result in some cases is due to the existence of a little CO_2 which increases the percentage of volatile matter.

Analysis of Yellow Ores.

	1. Original	2. Washed	3. Calculated free from impurities
	per cent.	per cent.	per cent.
Fe_2O_3	72·57	82·47	89·09
H_2O	10·17	10·10	10·91
CO_2	3·50	—	—
Insoluble residue . .	6·26	5·41	—
Soluble gangue . .	7·50	2·02	—
	100·00	100·00	100·00
$\frac{Fe_2O_3}{H_2O}$	1 : 1·25	1 : 1·09	1 : 1·09

The results of analysis of the minerals found in this mine therefore give no support to the formula for the yellow ores usually given—namely, $2Fe_2O_3.3H_2O$—though it may be found elsewhere. Later on mention will be made of some experiments made on precipitates of hydrated oxide of iron prepared under varying conditions, which will have a bearing upon the question of the origin of these ores. First, however, other minerals associated with these deposits may be described.

Amongst the ore brought up from the mine occur occasionally

knobby lumps which in most cases are almost black when broken across and are usually coated with a yellow ochreous ore. Sometimes indications of pyrites are seen, and occasionally the interior of the lump will disclose the yellow, brassy colour of pyrites. The outside also shows oxide of iron in pseudomorphs after pyrites, cubes and other forms in which pyrites crystallises. More rarely the surfaces of the pseudomorphs appear curved, as though they had assumed the external form of crystals of spathose, though they are not composed of that mineral.

Analysis of specimens of this 'Black Mundic,' as the miners call it, show that it contains about 58 per cent. of metallic iron, and is combined with water in the molecular proportion of 1 : 1 ; it gives a brown streak and powder and is undoubtedly *brown haematite.*

BLACK MUNDIC.

	per cent.
Fe_2O_3	84·76
Water, Carbon dioxide	11·57
Insoluble residue	2·66
Soluble gangue	0·926
Sulphur	0·084
	100·000

$$\text{Molecular ratio: } \frac{Fe_2O_3}{H_2O} = \frac{1}{1\cdot 18}$$

In the specimen of which an analysis is given the greater part of the sulphur has been removed, though more is left than is found in an average sample, which would contain about 0·020 per cent.

The mass of the ore in this mine, and the same is true of all the similar deposits in this district as well as in the Forest of

Dean, is embedded in a rock which is more or less completely dolomitised limestone. In fact, pure limestone only seems to occur in the form of crystals of calcite which have been formed subsequently. Analyses of the rock are given.

COMPOSITION OF SURROUNDING ROCKS.

	1	2	3	4
	per cent.	per cent.	per cent.	per cent.
$CaCO_3$ . .	58·14	55·54	50·53	92·75
$MgCO_3$ . .	37·40	41·16	37·15	5·69
$FeCO_3$ . .	1·56	1·82	1·98	—
$MnCO_3$ . .	0·73	0·53	—	—
Fe_2O_3 . .	0·75	0·32	1·23	0·87
Al_2O_3 . .	0·21			
Insoluble residue	0·87	0·84	9·56	0·49
	99·66	100·21	100·45	99·80

No. 3 was picked up at random as being fairly representative of the siliceous variety of dolomite, and No. 4 is a much less dolomitised rock. The relations of the carbonates will be seen better by calculating all to 100 parts of $CaCO_3$.

	1	2	3	4
$CaCO_3$ . .	100·0	100·0	100·0	100·0
$MgCO_3$ . .	64·4	74·1	73·5	6·3
$FeCO_3$ . .	2·6	3·3	3·9	—
$MnCO_3$ . .	1·2	0·95	—	—

The iron and manganese carbonates are thus seen to be comparatively unimportant constituents of the rock mass.

As to the mode of formation of these deposits there have been two principal theories which are fundamentally opposed. The one, now practically out of date, is that the iron came from below, being carried upwards into the limestone beds in the state of vapour by the force of the volcanic gases liberated from the fluid interior of the earth, or alternatively in the form

of a sulphide, which was subsequently altered into the oxide. This explanation is discredited by the simple fact that in all cases in this district the bulk of the ore is in the uppermost beds of the Mountain Limestone and fails altogether at a moderate depth.

The more recent theory is that the ore was introduced from above in a state of solution, and coming into contact with limestone a bodily interchange took place by which oxide of iron was precipitated and took the place of the limestone, which was removed partly in the circulating waters as a soluble calcium salt, and partly as gas in the form of carbon dioxide.

In general terms this is the explanation which holds the field at the present day, and the only possibility of difference of opinion is in the details of the chemical reactions which occur in the passage of calcium carbonate into haematite, and in the source and nature of the ferruginous waters.

Sections of this mine as well as of Mwyndy and Trecastle show that Triassic beds lie nearly horizontally upon the inclined beds of Carboniferous Limestone and Millstone Grit shales. The Triassic beds are believed to have been deposited at the bottom of inland seas which had, no doubt, been cut off from an outer ocean. In these inland seas the water might be gradually evaporated, and the density of the liquid increased by the concentration of the salts. We have an illustration of this in the great salt deposits of Stassfurth, where the various salt minerals are arranged in beds one above another, and have no doubt assumed this position by the successive deposition of various mineral species as evaporation went on. These minerals included *rock salt*, *Polyhalite* ($2CaSO_4,MgSO_4,K_2SO_4,2H_2O$); *Kieserite* ($MgSO_4.H_2O$), *Carnallite* ($KCl,MgCl_2.6H_2O$), *Bischofite* ($MgCl_2$), and *Tachydrite* ($CaCl_2,2MgCl_2,12H_2O$).

These formulae are given to show the prevalence of magnesium salts, because that element also has to be taken into

account in considering the deposition of these iron ores. One point in which the Stassfurth deposits do not help us is in showing where the iron came from, seeing that it does not form any great feature in them. But we know that some of the Triassic rocks are also called New Red Sandstones from the prevalent colour due to iron oxide. So that we may perhaps be justified in assuming that from one source or another the Triassic sea water contained more iron in solution, though otherwise very similar to other sea water. We know from Professor Clark's calculation of the average composition of the earth's crust that the two oxides of iron exist to the amount of 6 per cent. of the whole crust.

There are two possibilities as to the time when the replacement of the limestone by iron oxide took place; it may have been when the Triassic sea had as its bed the upturned edges of the Carboniferous Limestone, or it may have been at a later geological period, after the Triassic beds had been formed and consolidated, and percolating waters dissolved out iron and magnesium from the red rocks, and passing down through fissures, guided by the impervious beds of Millstone Grit shales, were able to act chemically upon the limestone.

A significant fact is that the replacement of the limestone by iron seems very generally to have been accompanied by dolomitisation of the contiguous limestone. Experiments made do not show that rhombs of calcite when suspended in a solution containing 10 per cent. $MgCl_2$ become to any extent dolomitised within any reasonable time, though, perhaps, given geological time it might happen.

The reaction between limestone and ferric chloride solution (assuming that to be the form in which the iron exists) is expressed by the equation—

$$3CaCO_3 + Fe_2Cl_6 + Aq. = 3CaCl_2 + 3CO_2 + Fe_2O_3 + Aq.$$

Experiments made (still unfinished) seem to point in the first stage to the formation of a hydrate of ferric oxide approaching the formula $Fe_2O_3.3H_2O$, when a rhomb of calcite is suspended at the ordinary temperature in a dilute solution of ferric chloride until the liquid is completely decolorised, which takes about a week.[1]

At higher temperatures, and on standing at the ordinary temperature the body formed varies from $Fe_2O_3.2\frac{1}{2}H_2O$ to $Fe_2O_3.2H_2O$, but I have not succeeded in obtaining in that way a product with less than the 1 : 2 proportion of water. A sample of rust formed naturally was found to have the molecular proportion 1 : 2.

It is stated that by long boiling at atmospheric pressure the higher hydrates are reduced to $Fe_2O_3.H_2O$, though the writer has not been able to confirm this by experiment. Ruff found that under pressure the colloidal ferric hydroxide formed by precipitation by alkalies became converted into hydrates of definite composition, the particular hydroxide formed being a function of the temperature. The colloidal hydrate with an indefinite water content between 30° and 43° C. became converted into a yellow granular powder having the water content and specific gravity of *limonite*, $2Fe_2O_3.3H_2O$; between 43° and 63° C. it changed to yellowish red with the composition and properties of *göthite*, whilst above 63° C. it altered to a brick-red substance with the composition of *turgite*, $2Fe_2O_3.H_2O$. The anhydrous oxide was only obtained at high pressures above a temperature of 150° C.

Applying this to the problem of the formation of these ores, it is probable, therefore, that no intermediate formation of

[1] These experiments with rhombs of calcite showed that the mineral was attacked only on the outside, and this conclusion is confirmed by examination of a microscopic section of dolomite in process of being haematised, where the individual crystals can be seen partially replaced by ferric hydroxide, but only on the outer surfaces, the interior showing no traces of haematite.

ferrous carbonate takes place, but a mass of oxides of various degrees of hydration is first formed, which subsequently loses water and finally results in the mixed medley of ores which constitute these deposits.

What would be the relation as regards bulk in the replacement of limestone by iron oxide ? The specific gravity of calcite is 2·7, whilst that of göthite is 4·0, which indicates that there will be a change of volume in the reaction. The equation shows that 300 parts by weight of calcite are replaced by 178 parts of a hydrate of the composition and density of göthite. According to their relative densities these weights (in pounds) would occupy respectively 1·8 c.ft. and 0·71 c.ft., an enormous contraction. Probably this would not be felt all at once, because the hydrates first formed, by adsorption of water, would be relatively very bulky. But as contraction took place cavities and fissures would be formed and the magnesian waters would get access, and this might account for the dolomitisation of the limestone, where it had not been dolomitised at the time of the deposition of the Mountain Limestone.

To ascertain whether any trace of chlorine remained to show the source of these deposits the writer mixed together all the weekly samples taken of the ore consigned to a certain firm for the period between January 1 and December 31, 1920, and thus got a very representative joint sample of the ore. He treated 200 grams of this sample with distilled water and determined the chlorine which the solution contained. The total soluble matter amounted to 0·034 per cent., and of this 0·0035 per cent. was chlorine. Sulphuric acid amounted to 0·0098 per cent., and 0·0212 was iron oxide and lime. We may say that practically no trace of its origin from sea water remains.

By the courtesy of the Glamorgan Haematite Iron Ore Co., Ltd., the writer is able to give the full analysis of the above

sample. It represents the average of all the various qualities of ore comprised within the boundaries of the workings, taken weekly over twelve months jointly with a representative of the receivers. The average moisture was 5·722 per cent.; the other constituents in the ore dried at 100° C. are given:

	per cent.
Iron	53·65
Oxygen equivalent	22·99
Alumina	0·96
Manganese oxide	0·12
Lime	4·47
Magnesia	0·51
Silica	6·66
Phosphorus	0·014
Sulphur	0·022
Oxygen equivalent to P and S	0·051
Chlorine	0·003
Carbon dioxide	3·20
Combined water	7·45
Copper and Lead	unweighable traces
	100·100

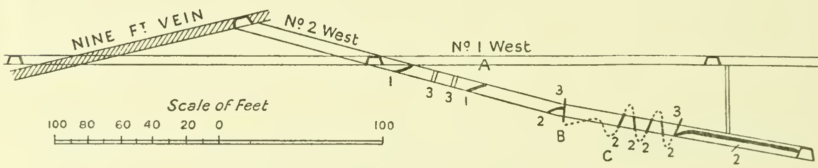
The greater part of this paper is devoted to the iron ores as found at Llanharry; there is little need to dwell upon those which have been worked in other parts of this ore field. Specimens from the Garth, from Trecastle, and from Wenvoe have been examined, and analyses of specimens from Mwyndy and Trecastle are given in Mr. Stephen Vivian's paper in the *Transactions of the South Wales Institute of Engineers*, and also in Principal Sibly's memoir. The principal point is that these ores are all of the same general character as the Llanharry ores, differing in richness and, in the case of the Mwyndy ore, in phosphorus content, for whilst Trecastle and Llanharry were both very low in that impurity, the analysis of the Mwyndy ore showed 0·132 per cent. P. The Garth ore on the average was much lower in iron, although a specimen picked up at the mine gave 47·95 per cent. metallic iron and 0·023 P. Ore

has been worked at Rudry, Whitchurch, and the Mumbles, but there are no records of their chemical character. The ore at Whitchurch must have differed from the others, for it is described as being situated at the bottom of the Carboniferous Limestone. Small quantities of iron ore are also reported from the Silurian beds at Rumney, near Cardiff, but not in workable quantity.

This concludes the list of places in which iron ore has been found ; borings are being made in other parts, but at present there is nothing to record about them.

OUTBURSTS OF GAS AND DUST AT TARENI ANTHRACITE COLLIERY.

By John Standidge.



1. Lower Black Vein
2. Brass or Peacock Vein
3. Faults

A, B, C — Position of Outbursts

Vertical Section illustrating Mr. Standidge's remarks on Outbursts at Gleison Pit, Tareni.

OUTBURSTS OF GAS AND DUST AT TARENI ANTHRACITE COLLIERY.

By John Standidge.[1]

On reading Mr Roblings' paper on the recent outburst of gas and dust at Ponthenry Colliery, a record of similar outbursts, which occurred some years ago at Tareni Anthracite Colliery, would, I thought, perhaps be of some interest to the members of the Institute.

In 1908–9 the upcast shaft at this colliery was deepened from the Red Vein, which lies at a depth of 92 yards, down to the Big or Nine Feet seam, a total distance from the surface of 435 yards. Main roads were then driven out east and west through the shaft pillar along the strike of the seam. The dip of the strata at the bottom of the shaft is approximately 18 inches per yard, in a southerly direction.

The measures at this colliery in the upper seams are divided into two parts owing to the erosion of the valley, which forms the course of the Tawe River. The valley at this point is 1400 feet wide. No attempt had been made to work the Red Vein under the river on the north side of the pits, as it was almost certain that, taking into consideration the rise of the strata northwards, this seam would be denuded, and that a pair of narrow roads would, even if the seam was present, run a very grave risk of tapping the water. Similar attempts at two or three places in the valley had proved disastrous, and it was considered best under the circumstances to leave well alone, and confine the Red Vein workings to

[1] Published after his death.

the south side. More recently a borehole was put down on the south-west side of the Tawe River, with the object of proving the depth of the solid rock. This was carried down to a depth of 225 feet, and when abandoned was still in boulders and sand.

After sinking down to a depth of 435 yards and going into the matter fully, it was decided to drive across the valley from south to north, with the object of working a large area of Brass Vein which was expected to be 40 yards vertical below the Big Vein. The Ynisarwed seam on the opposite side of the mountain being available, levels were taken across, and it was found that, taking the gradient as ascertained near the pits, no serious displacement of the strata need be anticipated, unless of course neutralising circumstances occurred. At the same time it was expected that disturbed ground would be met with.

In December 1913 two cross measure drifts were started from the Big Vein on the west side of the pit, to be driven approximately north. No. 1 heading was intended to be level, and was expected to intersect the Brass Vein at a distance of, say, 120 yards, making allowance for the measures flattening out to some extent. After advancing in No. 1 West for about 40 yards very serious disturbances of the strata were met with, the measures being nearly vertical for some distance. At a distance of 60 yards a small rider of very soft coal about 2 feet thick in almost a vertical position was passed through. When the heading had advanced beyond this seam a further 10 yards (shown on the plan at A) very strong blowers of gas were given off from the seam, and the heading was laid off for some days. During the evening of April 15, 1913, the overman stated that loud reports had frequently been noted during the shift at this point, and that most of the timbers were broken. Next morning a set of repairers were told off

to double or renew these timbers, under the supervision of the undermanager and fireman. They had scarcely started this work before a very loud report was heard, and without any further warning an outburst of gas and dust took place, between the overman and repairer on the inbye side and the undermanager and repairer on the outbye side. The undermanager and repairer stated that they were blown back for some distance, but were, however, able to return to the cross-cut, where there was a good supply of fresh air owing to the doors being blown open and remaining so. A strong current of air was at once diverted along the air pipes to the two men entombed, and after clearing the accumulation of gas in the heading an effort was made to clear the dust. Owing to the fineness of the material it was decided to brace a number of rails together and drive them through the fall. After about nine hours both men were got out, and with the exception of shock and bruises were not much the worse for their experience, although there is no doubt that they had been unconscious for a considerable time. From this fall about 300 trams of dust were filled, the width of the opening being only about 3 feet 6 inches.

The parallel heading (No. 2 West) was also being driven down at the same time, dipping about 12 inches per yard, and similar ground was encountered. At a distance of 66 yards (B on plan) a downthrow fault was struck, and on going down 4 feet a seam of very soft coal was found, which eventually proved to be Brass Vein. On the afternoon of June 6, 1913, having got through the seam, which was 2 feet 7 inches thick, the leader of the shift was cutting out the side for a pair of timbers when again very loud reports were heard, and another outburst of gas and dust took place. The leader of the shift was suffocated, and was eventually found buried in dust in a vertical position, at the end of the air pipes, about

5 yards from the face of the heading. Fortunately, the two assistants accompanied by the fireman were bringing down some timber at the time, and it was no doubt due to this that they escaped, and also that as a precaution electric lamps were hung along the heading, all ordinary safety lamps being put out. The dust in this case filled up the heading for a distance of 66 feet against a gradient of 12 inches per yard, and, in addition to this, dust 5 or 6 inches thick was found on the floor for a considerable distance back. Altogether 140 trams of dust were filled out of the heading before the face was reached. It was then found that large cavities had been formed in the seam both in front and at the sides.

It was thought that after this outburst the pressure would be relieved, and that little further trouble need be anticipated. On driving a further 70 feet this seam was passed through four times, due to two complete saddles and depressions in the strata, after which an upthrow fault was struck. On going up and finding the seam this was found to be in its normal state. After driving about 20 yards beyond this fault, development headings were turned to right and left. When twelve stalls had been opened up a very heavy weight was experienced, which came on so suddenly that all the workmen had to retire, leaving their clothes in the workings. On inspecting next day it was found that the roof had lowered to such a degree that it would be necessary to start at the point C to open up the workings again. It was known that the strata at this point was almost vertical, and it was decided to start this work on Saturday afternoon. The most serious outburst of gas and dust took place in December 1914, on taking out a pair of timbers at this point, being preceded by reports which increased in intensity. The roads back to the upcast pit were filled with gas, and also the main intake, which is a cross measure drift from the Red Vein, was filled for a distance

of 50 yards for some considerable time. The quantity of air in the intake was normally 25,000 cubic feet per minute. Two of the assistants and the fireman, who were young men, fortunately were able to get away quickly, turning up into the intake and escaping. The timberman or leader of the shift, who was an older man, was suffocated, and also a pony standing in the cross-cut at the top of the heading. It will be seen that a large quantity of gas was given off. The quantity required to fill up the roads back to the upcast would be approximately 110,000 cubic feet, without taking into consideration the volume passing to the upcast for the period that the ventilation was suspended. From this fall 600 trams of dust were filled.

A sample of coal taken from where the second outburst took place has been examined by Mr. Seyler. The lumps crumbled at touch to a powder. The powder produced was found to grade as follows :

Retained by 8 sieve . . .	1·5 per cent.
,, 16 ,, . . .	0·9 ,,
,, 36 ,, . . .	8·6 ,,
,, 100 ,, . . .	36·2 ,,
,, 200 ,, . . .	16·5 ,,
Passed by 200 ,, . . .	36·3 ,,
	100·0

In this sample, only 54 cubic centimetres of occluded gases were given off from 100 grammes of the smaller lumps, the average for normal anthracite being as high as 500 to 600 cubic centimetres. It is not meant to infer that because anthracite contains a larger amount of occluded gases these seams are more fiery in working. My experience is quite opposite to this, and points to it being possibly due to the extreme hardness of anthracite coal.

The occluded gases contained 90 per cent. of carbonic acid, and in this connection it may be mentioned that temperatures of 155° F. were recorded in the small coal, before the accumulation of dust was cleared away. The sides of the seam were hot for some weeks. The high percentage of carbonic acid appears to show that the friable coal from the points where the outbursts took place is very susceptible to oxidation.

In driving the cross measure drifts numerous cavities or pockets were noticed in the strata, and a likely explanation of the outbursts would seem to be that pockets of this nature acted as reservoirs for large quantities of gas stored at very high pressure.

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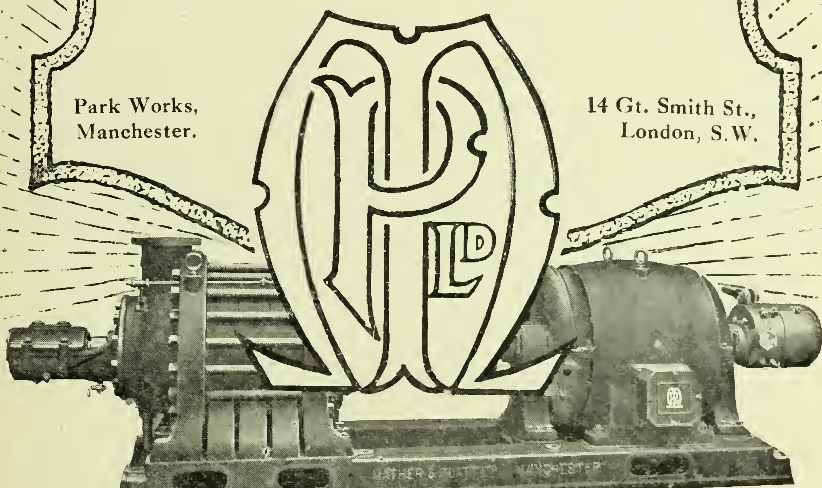

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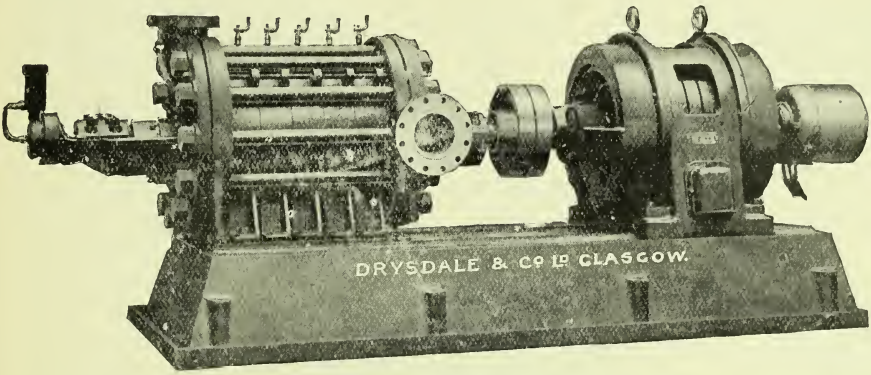

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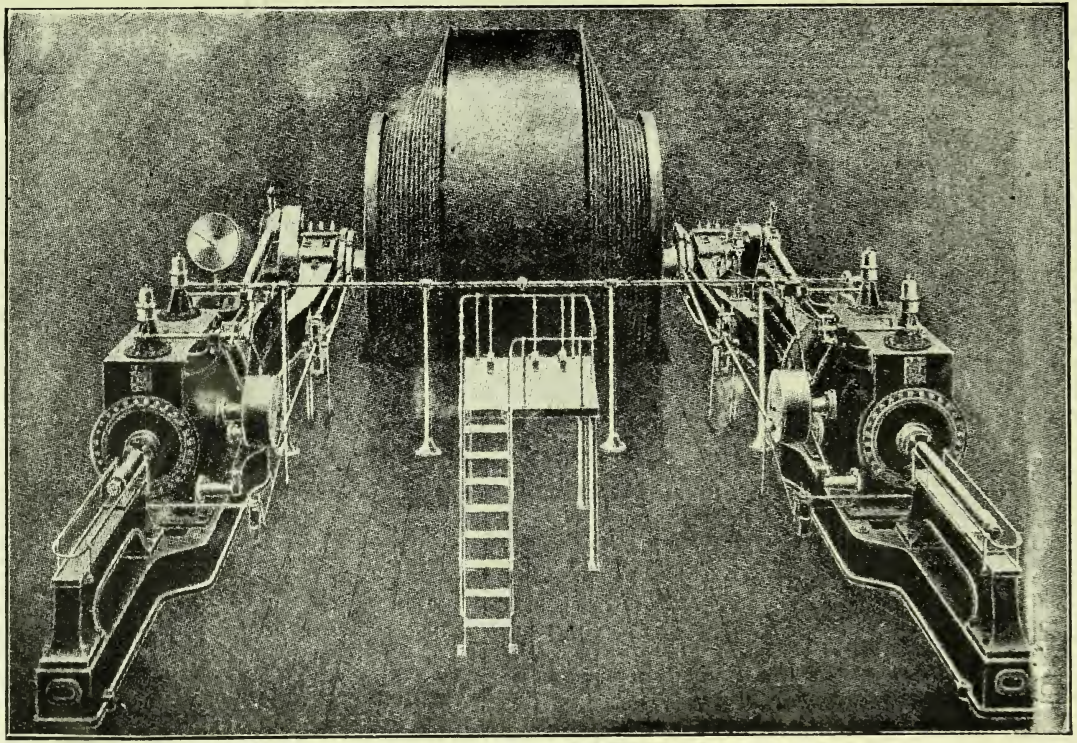
Patentees & Sole Manufacturers of
Patent "GRIPOLY" Solid Woven Belting
with the indestructible edges
Patent "GRIPOLY"-HERCULES BELTING.
MAXIMUM EFFICIENCY
Godbold



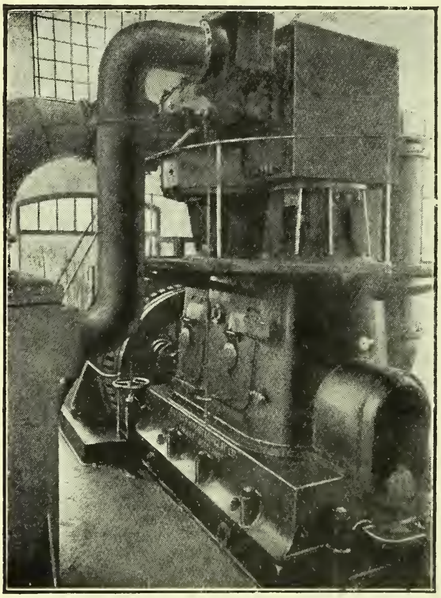
FULLERTON, HODGART, & BARCLAY, LTD

PAISLEY

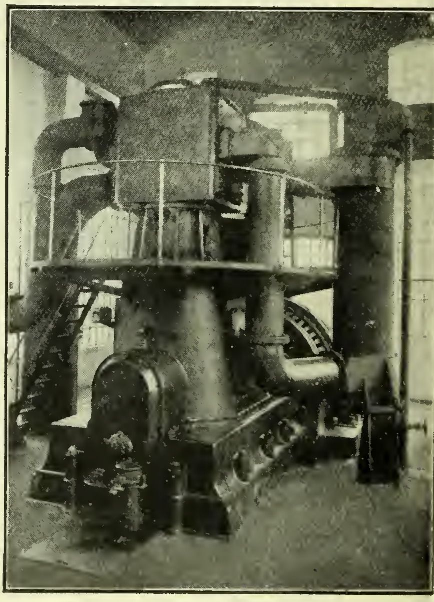
Code :
A B C 5th Edit.,
Engineering,
Western Union,
Marconi Inter.

Telephones :
2163-4 Paisley
Private Branch Exchange)
Telegrams :
"Vulcan, Paisley."

Vertical Motor-Driven Two-Crank Two-Stage Air Compressor.



FRONT VIEW



BACK VIEW

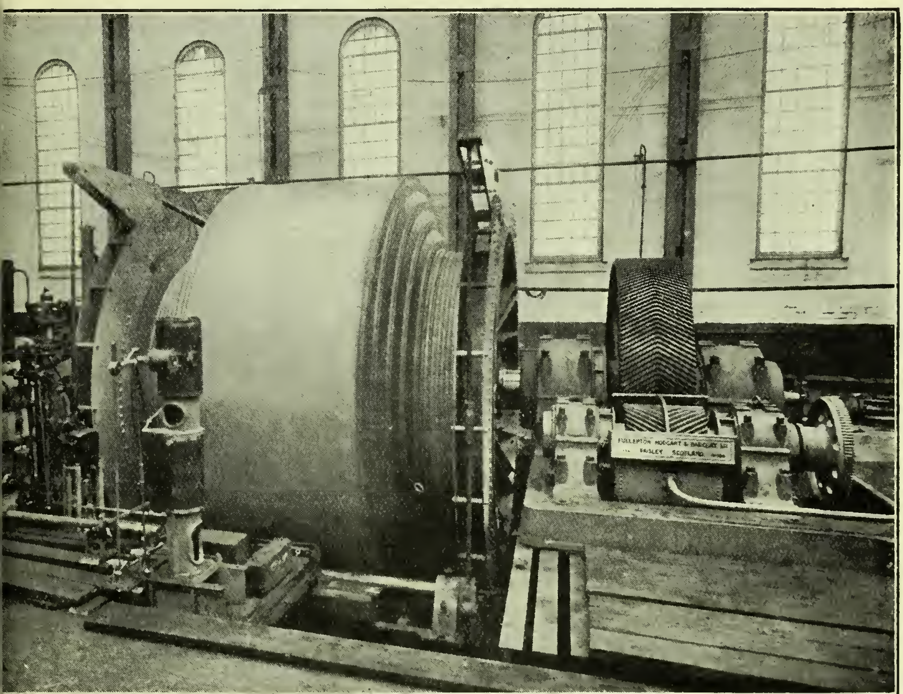
Capacity 6,625 cubic feet free air per minute. Pressure 75/100 lb. Speed 214 r.p.m.

FULL PARTICULARS ON APPLICATION.

Representative for South Wales :

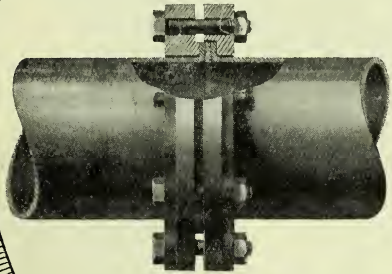
Estd. 1838

Fullerton

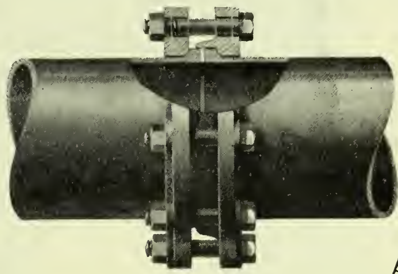


LIGHT LAPWELDED WROUGHT IRON AND STEEL TUBES

With Joints (as illustrated) for Water, Steam, and Air at high and low Pressures.



Stewarts Nº1. Loose Flange Joint.



Improved Albion Loose Flange Joint

SPECIALLY ADAPTED FOR USE IN COLLIERIES

MAIN STEAM PIPE INSTALLATIONS.

LAPWELDED IRON AND STEEL BOILER TUBES.

For Locomotive, Marine and Multitubular Boilers.

STEEL PLATES — STEEL CASTINGS

ZINC SHEETS — ZINC BOILER PLATES

STEWARTS AND LLOYDS L^TD.

GLASGOW, 41 OSWALD ST. *BIRMINGHAM*, BROAD ST CHAMBERS *LONDON*, WINCHESTER HOUSE, OLD BROAD ST

CARDIFF OFFICE AND WAREHOUSE,
132 BUTE STREET.